A Web-based Rapid Prototyping and Clinical Conversational System that Complements Electronic Patient Record System

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Abstract

Even the most extensive hospital information system cannot support all the complex and ever-changing demands associated with a clinical database, such as providing department or personal data forms, and rating scales. Well-designed clinical dialogue programs may facilitate direct interaction of patients with their medical records. Incorporation of extensive and loosely structured clinical data into an existing medical record system is an essential step towards a comprehensive clinical information system, and can best be achieved when the practitioner and the patient directly enter the contents. We have developed a rapid prototyping and clinical conversational system that complements the electronic medical record system, with its generic data structure and standard communication interfaces based on Web technology. We believe our approach can enhance collaboration between consumer-oriented and provider-oriented information systems.

Keywords:

electronic medical record, computer-based interview, rapid prototyping, clinical information system

Introduction

Modern clinical information systems provide a wide variety of standardized central and departmental clinical repositories. However, even the most extensive clinical information system cannot be fully responsive to all the ever-increasing, ever-changing, and highly specialized demands associated with clinical practice and research. The primary target data of the current electronic medical record system are the ones that are generally accepted as well standardized and clinically or managerially important. However, clinical care and research frequently require more extensive information that is loosely structured.

Despite efforts to support the highly unstructured data in clinical systems by measure of multimedia and free text, intermediately structured clinical data such as clinical rating scales, survey questionnaires, research protocols, practice guidelines, patient education programs, and structured clinical interviews are not being sufficiently supported. This is partly because such data have been regarded as inherently insignificant, not cost-effective, or too difficult to model and integrate into an electronic medical record system. This is also due to communication and management barriers between the information system and the clinical department as well as the anticipated difficulty of continuously supporting such complicated demands.

However, all the clinical details are necessary both for better patient care and for better clinical research. These include important clinical information that a paperless medical record system can hardly be achieved without providing them. Most of the rating scales and evaluation protocols are still primarily pencil-and-paper-based. Although clinicians and researchers can learn to design and manage their own electronic forms and tables, there is no easy way to integrate them into the main electronic medical record system.

The medical history is still mostly obtained in a face-to-face patient-physician interview, an approach that is expensive in terms of physician time and subject to a variety of errors that could be reduced with information technology [1 - 4]. Whereas rating scales and questionnaires have relatively simple forms, the structured clinical interview with response monitoring and conditional branching is complex. But all of them involve collecting clinical information in a structured encounter with a patient or health care provider and managing less-structured and more-detailed clinical information that can hardly be encoded completely. Thus, all can be viewed as a spectrum with the simpler forms on one end and the more complex interview on the other end.

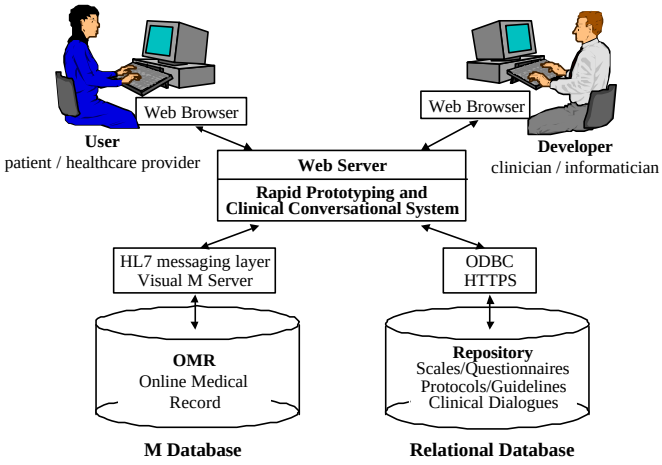

Figure 1. System architecture of the rapid prototyping and clinical conversational program.

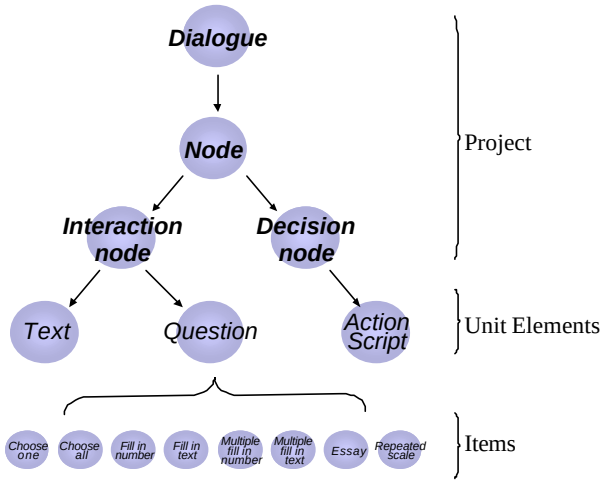

Figure 2. Clinical dialogue object model.

The Center for Clinical Computing at Beth Israel Deaconess Medical Center, Harvard Medical School, has developed Converse [5], a computer-based interview program and the OMR (online medical record) [6], an electronic medical record system. The diffusion and acceptance of the World Wide Web clearly offers a new opportunity. Clinicians and patients have easy access to the Internet and become accustomed to operating Web browsers. This paper describes a rapid prototyping and clinical conversational system that allows efficient modeling and easy integration of intermediately structured clinical information into an electronic medical record system. Our method uses Web technology and a centralized reusable dialogue object model. We believe that enabling clinicians to create and manage their own computer forms, protocols, and clinical dialogues is an essential aspect of integrating sophisticated clinical information into a clinical information system.

Materials and Methods

System Environment

The rapid prototyping and clinical conversational system is based on top of the CareWebTM system architecture of structuring and providing access to the legacy data in the OMR at Beth Israel Deaconess Medical Center [7] (Figure 1). It runs on a Microsoft Windows-NT server 4.0, Microsoft Internet Information Server 4.0, and Microsoft Active Server Extensions. The only application software required for the authors and the end users is a standard Web browser. Authors can compose and publish new objects for the clinical repository within a secured intranet.

Dialogue Object Model

As shown in Figure 2, the rapid prototyping and clinical conversational system has a hierarchical object model. The topmost dialogue object has the list of decision and interaction node objects, which in turn hold the list of unit element objects. The interaction node object displays information, asks questions of the end users (patients and health care providers), and waits for a response. An interaction node can have multiple text and question objects in any combination, so that the text objects can be used as section headings, comments, hints, explanatory texts with multimedia components, and so forth.

The question object currently has eight subtypes with different item objects:

- *choose one*
- *choose all that apply*
- *fill in the blank*
- *fill in the number*
- *multiple fill in the blanks*
- *multiple fill in the numbers*
- *essay (free text)*
- *repeated rating scale (multiple layers of choose-one type questions)*

The dialogue object has the flow control and page layout information for the lower-level objects, and it allows overriding information by assigning the corresponding attribute values of the lower-level objects. This strategy ensures both the consistency of a project's development as a whole and the reusability of each unit element object for different projects. We adhered consistently to the basic question-item-value abstraction barrier to provide a reusable question repository.

Authors can insert images and other multimedia components into any attribute allowed by the standard HTML tags. For each question object, authors can define a default response value, a specific range of acceptable answers, and the target object for conditional branching in response to the user's answer. The code generator in the project designer program automatically creates server-side or client-side scripts for these predefined actions.

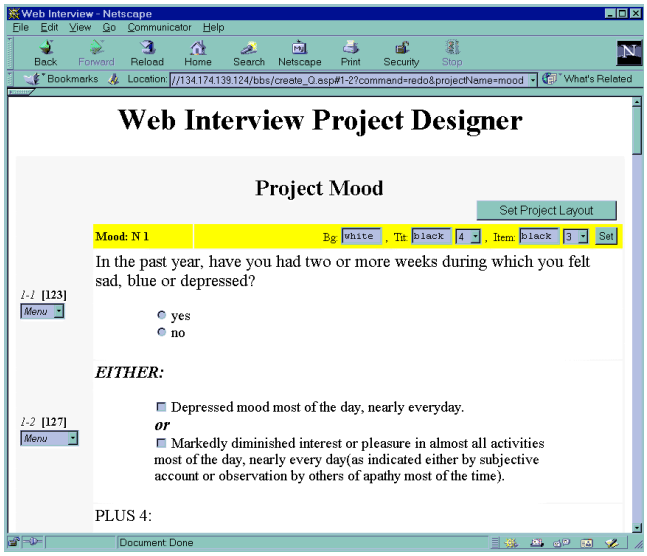

Figure 3. Project Designer

The decision node object that permits a truly interactive dialogue consists of executable scripts that control event flow and sequence, pass parameter names and values, trigger conditions (IF-statements), and fire actions (THEN-statements). Since authors may have different levels of computer skills, the decision node provides three levels of support. First, the no-script mode supports authors with no programming skill by providing menus. Second, the predefined, limited-script mode provides a well-defined, limited set of dialogue coding scripts that is managed and censored by a meta-linguistic translator program. Finally, the high-level full-script version provides full compatibility with the Microsoft Active Server Page scripting technology, including the creation and use of separately compiled objects. Eventually, an automatic code generator translates all developed interviews of different modes into a general purpose Web-based computer programming language code, Microsoft Visual Basic Script.

Project Designer

The standard Web browser functions as an integrated development environment (Figure 3). Authors can gain access to the server through the secured intranet. They can compose, modify, rehearse, and publish their forms, protocols, and clinical dialogues simply by choosing menus and assigning values to attributes of each object displayed on a Web browser. The project designer program provides an intuitive and progressive means of project development.

Flow-Control Mechanism at the Decision Node

Checking input values, passing parameters, and querying clinical information are the basic flow-control mechanisms performed by sequential processing, repeated iteration, and conditional branching. Both client-side and server-side programming techniques are being used with different levels of sophistication. For instance, in the beginner's assisted mode, assigning the upper and lower range of user input for "fill-in-the-number" questions, or checking the "response required" checkbox in choose-one questions, automatically creates a client side Java script to control user input. However, in order to overcome the limited usefulness of the client-side scripting and the compatibility problems of different browsers and versions, the program provides a way of writing server-side scripts. In general, the server-side technique provides more detailed control but requires some programming skill.

All the longitudinal dialogue information including user responses throughout an interview are completely logged and can be used as variables for conditional branching algorithm at each node level, so that a paused interview can be re-started at any time at the same node with the same state variable values. During the process, subjects are allowed to navigate freely using the browser's back and forward buttons, and thus, they may respond multiple times to the same question. All of these responses are also captured, and multiple sessions for the same dialogue are allowed.

Capturing Responses to Relational Tables with Generic Structure at the Interaction Node

All user input is tagged with its submission time and the reaction time, which is measured as the interval between completion of Web page loading and user submission. The clinical dialogue repository has a "narrow-and-tall" type generic relational table based on the object-attribute-value model [8]. The program captures all user responses to each question and item and tags them with the submission time and reaction time. Although the value field assigns a generic rather than a proper data type for the corresponding questions and items, this generic data structure makes it possible to capture all the information in a single table in a consistent manner, despite the diverse data structures of the forms, protocols, and dialogues [8]. It also allows free user navigation and repeated answers. In addition, at the time when an author publishes a clinical dialogue, it automatically creates a normalized "wide -and-short" type relational table for each dialogue, which has specific attributes with the proper data type assignment for all the corresponding question and item objects. This table appends only one record for each session to capture only the latest user responses to the questions and items. Both tables can be used for clinical and research analysis. A summary, created at the end of each session, is based on these tables.

Results

Several programs have been implemented with the rapid prototyping and clinical conversational program and we have achieved many of our goals for an object-oriented and Web-based design. We believe that clinicians without

knowledge of database or Internet programming will be able to compose their own Web-based clinical dialogues after a few hours of training. Although decision-node programming requires script-level programming skill, most of the clinical rating scales and questionnaires without complex branching can be created without programming skill. For example, inserting only one question object of the repeated rating scale type was enough to build an automated form for well-structured rating scales such as BPRS (Brief Psychiatric Rating Scale) [9], which has 18 repeated scales measuring the severity of psychiatric symptoms. Algorithms with moderate complexity with some branching logics can be composed with virtually no programming skill.

To develop a truly sophisticated clinical dialogue with complex conditional branching algorithms requires script-level programming skill. For instance, using this program, we have rebuilt some of the most complex clinical interview modules [10] written in Converse [5]. The urinary tract infection program consists of more than 800 interaction and decision nodes. It evaluates urinary tract symptoms and signs, decides whether a urinary tract infection is present, prescribes antibiotic medication when needed, and provides information to help patients manage urinary tract infection themselves.

Self-evaluation forms and interactive clinical dialogue protocols that are available on the Web and effectively connected to the electronic medical record system are valuable tools allowing direct patient data entry into their medical record.

We have adhered to standard Web database technology so as to integrate the clinical dialogue objects into existing clinical information systems. The program can use the data in our clinical information system, and the clinical information system can also use the data in clinical dialogue repositories.

Conclusion

Within the constraints imposed by the Internet, our rapid prototyping and clinical conversational program provides a platform-independent standard interface, extended reach through the Internet, multimedia capability, reusable question objects, and a centralized clinical dialogue repository. When both the authors and the users of the clinical dialogue are familiar with Web browsers, new clinical dialogues can easily be developed and accepted [11,12,13], with minimal training and minimal software distribution, as an essential complementary part of the electronic medical record.

Other useful types of question objects such as the Likert scale, visual analogue scale, and graphic notation questions can be added to the eight question types listed earlier to extend the range of responses. There is a tradeoff between the functionality and the ease of use available with client-side versus server-side technology. Server-side programming provides virtually all the programming functionality but requires some programming skill. The project designer program automatically generates general-purpose program code, Microsoft Visual Basic Script, from the developer-built forms. This flexible structure allows virtually all programming functionality as well as the direct interface for skillful developers to use a standard programming language to manage the most complex tasks. It enhances the functionality of the former dialogue programming languages specifically designed to develop computer-based dialogues [5, 7] and, hence, it saves learning effort.

Although the current dialogue and its lower-level objects are reusable, they are not effectively connected to controlled vocabularies for data representation. Tight coupling of dialogue and question object to standardized biomedical vocabularies with semantic representation can enhance integration of more sophisticated clinical information to the electronic medical record system and, hence, to the clinical decision-making process. It would also help to bring clinical research information, such as clinical trial results, closer to the current electronic medical record [15].

Studies have demonstrated patient acceptance of computer-based interviews [16,17]. In some instances, there is even a greater willingness to disclose sensitive information to a computer than to a human interviewer [18,19]. However, it is not yet clear how patients may perceive a Web-based interview, perhaps because of a lack of consensus on the security and confidentiality issues of the Internet. More experience with secure tele-healthcare and online purchasing should enhance patients' acceptance of online interviewing.

Current trends indicate that increasing numbers of clinicians and patients will use the Internet for health care. Constraints inherent in the Internet today are likely to be improved with its rapid development. With the Internet used as the conduit, well-designed interactive clinical dialogue programs that are well integrated with a clinical information system may facilitate direct interaction by patients with their medical records, thereby leading to collaboration between consumer-oriented and provider-oriented computer information systems [20].

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