Architecture for a Federated Drug Reference in a Managed Care Environment

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We describe a model of drug information query management that supports the integration of various types of pharmaceutical information and the delivery of that information through a common interface. Our prototype drug reference system makes use of the World Wide Web client/server architecture as a front-end to federate this data. Although originally intended as an electronic Hospital Formulary, the system has been redefined as a result of input from physicians to include formularies of multiple managed care plans. The underlying database is designed for integration with an electronic medical record as well as education and research resources for faculty and students in an academic medical center environment.

INTRODUCTION

Selection of the most effective drug therapy for a specific medical condition that also meets a patient's insurance parameters is an increasingly difficult information decision point for physicians. Several hospital information systems provide drug interaction guidance as part of the patient record and there are several standalone and add-on packages for this purpose on the market [1]. Such systems provide part of the clinical solution. Studies have shown that upwards of 14% of physicians in office practice have unmet drug information needs [2,3]; and further, that pharmaceutical representatives, who influence prescribing habits, may contradict readily available information 11% of the time [4,5]. Comparison of results from cumulative meta-analysis of randomized control trials with clinical expert recommendations demonstrated that experts have not synchronized with accumulating evidence and that slow recognition may result in delays in acceptance of effective drugs and abandonment of possibly harmful therapeutic practices [6]. Beyond prescribing patterns, managed care plan formularies are becoming increasingly restrictive, complicating the appropriate selection of medications for optimal patient care and compliance [7].

The Integrated Advanced Information Management System (IAIMS) planning process at the University of Washington (UW) identified drug information as one of the highest reference priorities. Providing up-to-date drug information relevant to the need at the point of care became a realizable objective by combining electronic databases and the World Wide Web architecture as a means of distribution. A drug reference team composed of pharmacy, library and IAIMS staff began discussing an electronic version of the Hospital Formulary accessible through a Web browser in 1995. Input from clinicians and faculty led the team to design an inclusive group of "federated" resources to serve the needs of primary care physicians; the needs of researchers in accessing research and investigational drug information; the needs of faculty creating Web-based educational modules for students in medicine, pharmacy, and nursing; and the need for a library-style reference for general use. The prototype we describe is an open systems, distributed client/server application called the Federated Drug Reference (FDR).

BACKGROUND

Each year, the UW Drug Information Center publishes a drug formulary for the hospital under the authority of the Pharmacy and Therapeutics Committee. This pocket-sized guide is organized by generic name or therapeutic type with cross-references to common trade names based on a subset of information from the *USPDI Volume I Drug Information for the Health Care Professional* (*USPDI*) database [8], supplemented with UW specific dosage and cost data. Several tables (e.g., parenteral nutrients, suggested dosage adjustment schedules) are also included. To supplement the formulary, *the Micromedex Knowledge Bases* [9] became a local electronic resource in 1995. Currently, *Micromedex* is a text-based reference tool available at each clinic and nursing station via a Telnet session. The shortcoming of the interface is that it does not have an intuitively friendly graphical interface except on the Windows platform.

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Micromedex has indicated that a Hypertext Markup Language (HTML) or Standardized General Markup Language (SGML) version is under development.

The United States Pharmacopoeia (USP), a not-for-profit organization, provides authoritative, evidence-based information on drugs and drug products. The USP's peer-review consensus process involves 35 medical specialty and professional practice advisory panels that include more than 700 volunteers who objectively evaluate published data on drug products and issue unbiased. The complete *USPDI* database contains over 8,000 drugs, cross-referenced by established names and older non-proprietary names. Each drug entry includes information about the therapeutic category, indications, pharmacology, precautions, adverse effects, patient consultation, dosing information and dosage forms. The database includes overviews of therapeutic classes, such as antidepressants, followed by monographs of individual drugs, such as amitriptyline. The *USPDI,* which is organized according to severity, drug interaction information (e.g., drug-drug, drug-food) and general dosing, is particularly strong in adverse effects information. It includes drug uses and pharmacological information valuable for research and educational purposes. It has been cited by the federal government in the 1990 and 1993 Omnibus Budget Reconciliation Acts as an "official" compendium for use in patient counseling. The U.S. Pharmacopoeia intends to merge the database with recommendations from the *AMA Drug Evaluation Monograph Series* and add National Drug Code (NDC) numbers.

Beyond the UW Drug Formulary there are two other local sets of key data: 1) the research and investigational drug formularies maintained by the UW Pharmacy and 2) the growing number of closed or limited formularies from insurance companies that are contracting with Pharmacy Benefit Managers. UW physicians must prescribe medications for patients participating in one of thirteen managed care plans, each with its own formulary. Beyond the formularies for the State Basic Health Plan and UW, some formularies require the dispensing of a specific manufacturer's generic. Contracts with these health plans specify that formulary data must be available to the UW. Ideally, our physicians should be able to determine, for example, that Augmentin™ is on a particular formulary (e.g., drug and formulary search) by performing a quick lookup or by drilling down into the generic or category information. Some drugs are "formulary" but have specific requirements that must be completed before the patient receives the drug (e.g., prior authorization from the plan). We are working with King County Medical Blue Shield and Blue Cross of Washington to obtain their formulary data.

Despite some functional limitations to the web based model, we are developing an interface to this federated data because it minimizes remote client support and provides platform independence. This is important in our environment because computer use at the UW is split three ways: Windows, Macintosh, X-Windows. In addition, the Web architecture allows us to federate other resources through HTML anchors. For example, we plan to provide drug name level links to our local *Micromedex* database, UW Pharmacy and Therapeutics alerts and recommendations, Centers for Disease Control Prevention Guidelines and Immunization Information [10,11], drug structure and pill identification images, laboratory test reference (e.g., cost comparison for antibiogram), and other Web-based drug information sources.

METHODS

The core of the FDR is based on the *USPDI*, which is available in a plain text file format consisting of fields separated by a two-character identifiers. Each drug is grouped by category, and categories are divided into three principle groupings: 1) information common to all drugs within a category; 2) information specific to each generic drug group within a category; and 3) information specific to each dosage form within a generic group. These three sets of data make a natural data structure for the lookup tables shown in Figure 1.

Data from the UW and managed care plan formularies contain approved brand name drugs, along with the dosage form, unit of distribution and cost per unit. NDC numbers will serve as the primary key between the *USPDI*, local formularies and later the *AMA Drug Evaluation* data sets.

The USP maintains its data in a non-relational format called Dialog which is optimized for producing printed reference source. It is organized in long, content-rich fields separated by two-character field identifiers. It also contains various format tags, tables, and charts embedded directly in the text. As a result, a two-stage filter is required to convert the data to a relational model. The first set of filters separate each piece of data by its two-character field

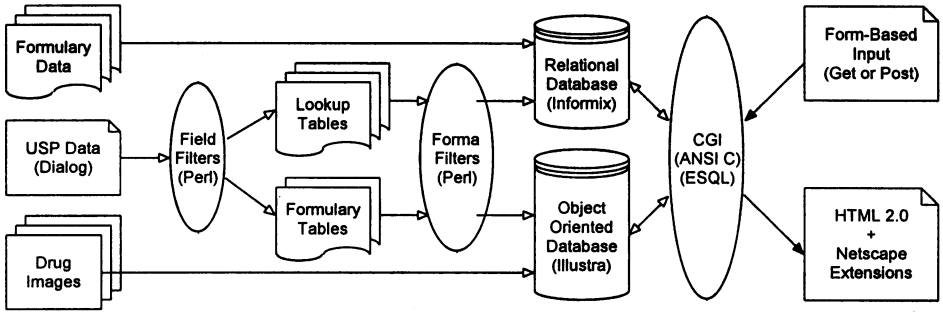

Figure 1. Data model for Federated Drug Reference.

identifier. Two distinct types of data arise from this process: lookup tables and content tables. Lookup tables consist primarily of fields that will be used in keyword searches. The lookup tables include fields for a unique identifier, a shortened name used for searches, a full name to be returned by searches, and a computer generated index used for "sounds like" (Soundex) queries. Content-based tables contain the rich, formatted text that usually provides background and general information.

The second set of filters convert pre-existing tags to a format accepted by the Web browser. These filters will convert embedded tables and charts into an HTML structure and change field identifiers to full descriptions. Finally, formatting that is not required by the Web interface or that is consistent among all occurrences of the data will be stripped out since such formatting is inserted on-the-fly by the server. All lookup table information is then inserted into a hybrid relational/object-oriented database. Quarterly updates to the data will require all information to be re-filtered and loaded.

Various programming languages were used to construct the data model shown in Figure 1. The field level filters are parsed by a Perl script that keys specifically on field identifiers embedded within the *USPDI* data. The pattern matching capabilities of Perl were also used in the format level filters to convert Dialog format tags to HTML. The heart of the interface, the Common Gateway Interface (CGI), is written in ANSI C, with database calls being made with *Informix* Embedded SQL/C (ESQL). The CGI framework has been organized into a dynamic C library to maximize modularity and provide reusable code. Input from Web-based forms is accepted by using either "GET" or "POST" methods. Information returned to the client is HTML 2.0 compliant with Netscape extensions.

RESULTS

The *USPDI* database was used to create the prototype Web interface illustrated in Figure 2. Searches can be made on drug name (Albuterol) or by category (antibiotics). Typing "albut" retrieves all drugs beginning with that root. Drug name searches can also be performed on synonyms or a Soundex pattern match. If more than one drug is matched, an intermediary "picklist" is provided. If exactly one drug is found, it is displayed in a default view. Users may view specific "chunks" of information such as physical properties, formulary cost and availability, and general dosing, or the entire document for a drug by selecting the appropriate link. Print, save and email functions are provided by the Web browser.

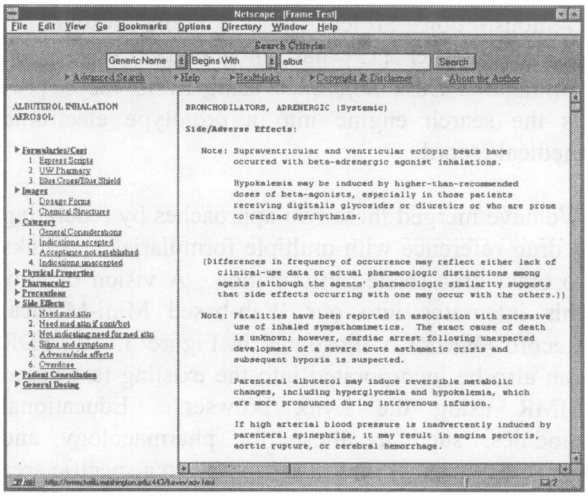

Figure 2. Prototype Web page for the FDR.

Searching a drug by category, such as "antibiotics" will generate a list of generic drug groups linked to specific drug names and information. Options are also provided to view general information for all drugs in the current category. Within each drug document exists all categories that apply to the current drug. Links to other related categories can also be generated at this point. For example, if the user is viewing azithromycin, s/he might see an additional link referring to the related category of "antibacterial systemic".

The beta version of the Web interface is being designed collaboratively with focus groups composed of physicians, nurses and pharmacists during summer 1996. During the beta period we will capture log data (e.g., computer address, date and time of request, query statement and displayed content), conduct small sample usability testing, and collect user comments through a Web feedback form. A drug information seeking survey will be conducted before production release and at the end of one year to determine if FDR impacts efficiency and quality of clinician drug prescribing behavior.

DISCUSSION

Other academic medical centers are prototyping Web-based drug information access for clinicians. The Medical College of Wisconsin & Froedtert Memorial Lutheran Hospital Drug Formulary [12] offers a typical formulary using the UNIX "htgrep" program as its search engine. It displays brand name, generic name, form, dosage and cost. The Clinical Demonstration Project at Columbia-Presbyterian Medical Center [13] has integrated a Web-based *Physician's Desk Reference* using *Folio Views* [14] as the search engine into a prototype electronic medical record.

We have merged these two approaches by federating a drug reference with multiple formularies and links to other drug-related information. A vision of how this integrates into our Web-based Mini-Medical Record (MMR) is illustrated in Figure 3. The FDR can also be incorporated into the existing text-based MMR using the Lynx browser. Educational modules, such as those for pharmacology and pharmacy courses, can also "jump" to a specific area of the drug reference using form-based "GET" commands.

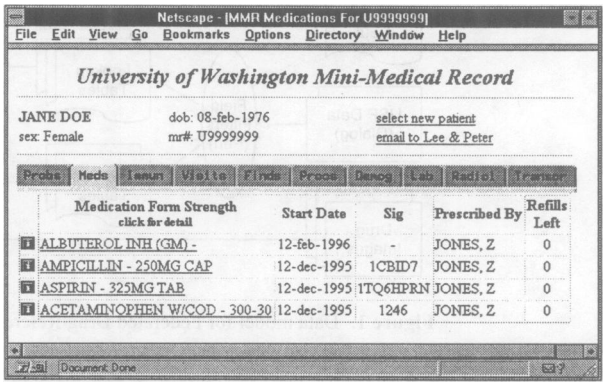

Figure 3. Prototype Web page for the UW mini-medical record. Clicking a drug name searches the FDR.

To enhance the performance of the search engine, we plan to move the descriptive data fields into the object-oriented engine to allow full-text searching. We will also incorporate the CGI library directly into the Web server's Application Programming Interface (API). Furthermore, we will investigate the addition of the Unified Medical Language System (UMLS) for term mapping [15, 16].

To enrich the data content, we plan to add images of drugs to the database to allow users to identify medications using a combination of visual properties (color, texture, shape) and drug attributes (interactions, side effects, brand names). We also have plans to add the UW research and investigational drugs to the database. Links to other UW sources such *Micromedex* can be built by the CGI using a form-based "GET" generated from the keywords of the current record. Potential external Web links include the Cutaneous Drug Interaction Database [17], Centers for Disease Control prevention and immunization information [10, 11], and *USPDI Patient Information Leaflets* [18].

License restrictions on use of the *USPDI* data and a potential need to restrict access to the formulary data raised several security issues. The current implementation simply restricts *USPDI* queries to the UW domain. Additionally, we could provide a "generic" username/password to our validated UW physicians, faculty and students who would like to access this resource at affiliated teaching hospitals. However, this does not adhere to the same rigor of the UW license management established for other commercial databases. Another option is to use the Secured Socket Layers (SSL) provided by Netscape products to encrypt data sent to Web clients. This

would provide the most security, but would also introduce additional maintenance overhead. Based on commercial developments in this area, we anticipate an acceptable solution before broad deployment of the FDR.

CONCLUSION

We have developed a model for drug information query management that supports the integration of network-based resources. The *USPDI* and drug formularies for managed care plans form the core data. This data is warehoused in a hybrid database structure to maximize the performance (relational database) and provide additional flexibility for content types (object-oriented database). The model supports a single, simplified interface for physicians at the point of care based on the Web client/server architecture. The model also supports a rich set of data for use in Web-based educational and research tools.

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