Prototyping an institutional IAIMS/UMLS information environment for an academic medical center*

By Perry L. Miller, M.D., Ph.D.
Associate Professor, Department of Anesthesiology
Director, Center for Medical Informatics

John A. Paton, Ph.D.
Director, Office of Academic Computing

Jeffrey I. Clyman, M.D.
Assistant Professor, Department of Anesthesiology
(Medical Informatics)

Seth M. Powsner, M.D.
Assistant Professor, Department of Psychiatry

Yale University School of Medicine
New Haven, CT 06510

The paper describes a prototype information environment designed to link network-based information resources in an integrated fashion and thus enhance the information capabilities of an academic medical center. The prototype was implemented on a single Macintosh computer to permit exploration of the overall "information architecture" and to demonstrate the various desired capabilities prior to full-scale network-based implementation. At the heart of the prototype are two components: a diverse set of information resources available over an institutional computer network and an information sources map designed to assist users in finding and accessing information resources relevant to their needs. The paper describes these and other components of the prototype and presents a scenario illustrating its use. The prototype illustrates the link between the goals of two National Library of Medicine initiatives, the Integrated Academic Information Management System (IAIMS) and the Unified Medical Language System (UMLS).

Computer networks are starting to link the major components of academic medical centers. As a result, it is now technically possible to access a growing number of information resources from academic workstations on the office desktop and also from clinical workstations in hospital wards and clinics. In the future, a vast number of both local and national computer-based information resources will be accessible, any of which could be relevant to a given clinical or research question.

The network-based connections among different computers that make such resources accessible represent only the first step in making the information available to clinicians, researchers, and staff. To take best advantage of this technology, the user will require a great deal of help to

- learn what information resources are available,
- determine which resources are likely to be most useful in solving a given problem,
- make an online connection to a selected resource,
- pass to the resource any relevant information that is already online, and
- interact efficiently and easily with the chosen resource.

Ideally, the computer itself should help the user with each of these tasks. The authors are building a set of tools to provide this type of assistance within an academic medical center. To explore the "information architecture" required to carry out these tasks, an experimental system has been implemented to

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demonstrate these capabilities. The system currently is implemented on a single Macintosh computer, but it contains in prototype form the various components that ultimately will be distributed over the institution's computer network.

The prototype was implemented on a single machine so that the various capabilities could be explored and demonstrated without the need to confront the difficult programming task of making the various components communicate over a network while running on diverse machines. With a single machine, the focus could be restricted to overall conceptual design issues.

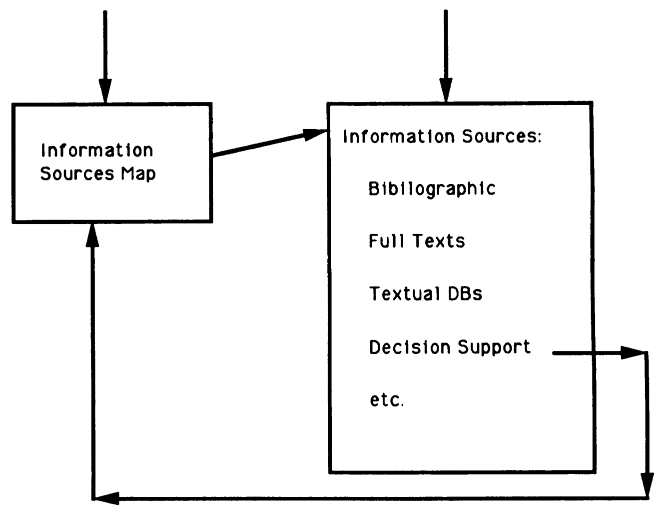
This paper describes the various components of the prototype, which include information retrieval, clinical advice programs, and an information sources map (ISM), as well as various tools that allow users to interface effectively with these components. The paper also describes the information architecture that allows these components to be tied together in an integrated fashion over a computer network. Finally, the paper presents a clinical scenario illustrating how the information environment could be used to enhance patient care.

INITIATIVES OF THE NATIONAL LIBRARY OF MEDICINE

The prototype was developed in the context of two initiatives of the National Library of Medicine (NLM). NLM's Integrated Academic Information Management System (IAIMS) program is designed to encourage academic medical centers to plan and implement an integrated institutional approach to information management for clinical practice, medical education, and biomedical research [1-3]. The Unified Medical Language System (UMLS) is a multi-institution collaborative project to build tools to help integrate online information resources, focusing particularly on the lexical terms used to describe medical concepts in different information systems [4]. The UMLS project currently focuses on the development, refinement, and dissemination of three principal tools: a "metathesaurus," which contains a glossary of terms together with their translation into a number of different coding languages; a network of semantic relationships among those terms; and an information sources map, to be described shortly.

The prototype described in this paper was developed initially as part of the authors' UMLS research, but it also has served as a pilot demonstration of key capabilities to be implemented on an institutional basis as part of an ongoing IAIMS effort. Thus, the prototype serves as a concrete demonstration of the close ties between the IAIMS and UMLS projects in terms of overall goals and of how the two initiatives can be combined productively.

Figure 1
Outline of the two central components of the IAIMS/UMLS environment



THE HEART OF THE INTEGRATED INFORMATION ENVIRONMENT

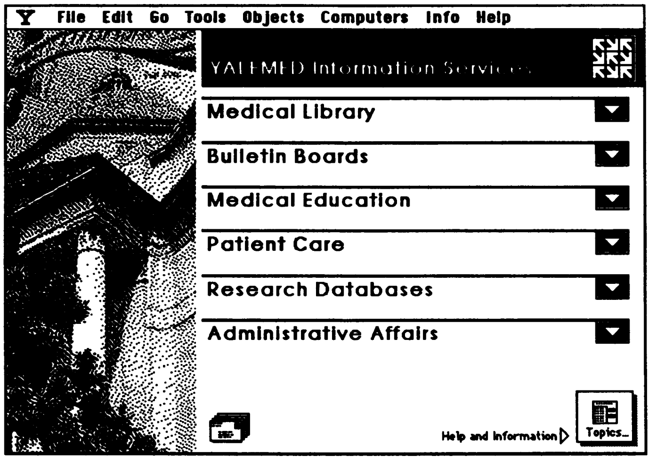
At the heart of the prototype IAIMS/UMLS environment are two components: a diverse set of information resources available over an institution's computer network and an active ISM (information services map), which can assist network users in finding and accessing information sources relevant to their needs (Figure 1).

Diverse network-based information resources

The IAIMS/UMLS environment is designed to facilitate access to a wide variety of information sources, both local and national. These information sources will be based in a variety of computers (including mainframes, minimainframes, workstations, and CD-ROM servers) and will be accessed through different mechanisms (including modem access and direct network access) using a variety of interaction protocols. Information resources will include bibliographic databases such as MEDLINE, miniMEDLINE, and Current Contents; a wide variety of textual databases; SQL-(structured query language-)based relational databases; clinical advice systems; and clinical databases of patient records, with appropriate safeguards for security and confidentiality.

Network users will be able to access these information sources directly or indirectly via the information sources map.

Figure 2
The initial screen of NetMenu, an operational prototype designed to facilitate access to network-based information resources from the desktop



An active information sources map

The diversity of resources accessible over an institution's computer network will expand rapidly over the next few years. To help users find the information they need, an ISM should provide active assistance in selecting and accessing relevant information sources. The ISM is, therefore, a database of information sources available on the network. As illustrated later in the scenario, the prototype ISM includes a number of capabilities to provide active assistance to the user:

■ **A prose description of each source.** The ISM contains a textual description of each information source to help in determining whether it might be relevant to the user's needs.

■ **A set of MeSH terms indicating the contents of the source.** Given a user query, expressed as a Boolean expression of search terms, the ISM should be able to suggest information sources likely to be relevant to that query. To provide for this capability, the ISM description of each information source contains high-level MeSH terms characterizing the contents.

■ **A protocol script to access each source automatically.** The ISM also includes an access script (a series of commands) that allows automatic connection to each information source over the network.

■ **An input template indicating the input data required by each source (if appropriate).** For each clinical advice system, the ISM may contain an input template listing the clinical data on which the advice is based. Thus, if the user of a clinical information system links to a decision support system via the ISM, any online clinical data can be passed to the latter system automatically. (This process is described in more detail below in the scenario.)

■ **The ability to translate a generic search expression into a specific search expression tailored to a given source.** As described in the clinical scenario, the ISM should be able to translate among available search expression languages to allow the easy searching of multiple databases.

Thus, the ISM can help the user select appropriate information sources, perform an automatic network-based connection to a chosen source, and pass any relevant online information to that source without user intervention. In the future, the ISM also may contain protocols to retrieve, merge, and synthesize information derived from multiple sources.

ACCESSING THE IAIMS/UMLS INFORMATION ENVIRONMENT

To help users access the IAIMS/UMLS environment described above, the authors have developed NetMenu [5], an operational prototype network menu of information services (Figure 2). NetMenu currently resides on a Macintosh, implemented using HyperCard. Behind the NetMenu front-end are underlying communications programs that use local and national networks and phone lines to reach local and remote information resources.

Using NetMenu, information services may be reached through pull-down menus in different categories, such as library services, bulletin boards, education, patient care, research databases, and administrative affairs. The same services also can be reached indirectly by clicking on the names of the categories to obtain a description of each information service available in the category. Each description screen also includes a button to access the service described. Finally, the same description screens can be reached from a comprehensive index of services. The variety of pathways is intended to meet the needs of users with different levels of experience.

From the user's perspective, the desktop computer is a window on the world, and in this case, it is a world of services rather than computers and networks. Information services appear as if they were computer programs and can be integrated with other programs and utilities within the personal computer itself.

NetMenu provides a prototype academic workstation, which sits on the desktop in a user's office and facilitates access to the world of network-based services. A similar capability currently is being developed for a clinical workstation designed for hospital and clinic use. Yale New Haven Hospital is installing a commercial hospital information system called the Clinical Care Support System (CCSS). Each CCSS terminal will be an IBM PS/2 workstation connected to the hospital computer network, which is connected in turn by a gateway to the university campus network, which includes the School of Medicine. (Security safeguards will protect the confidentiality of patient data.) Using this network, CCSS workstations will be able to connect to CCSS and also to the IAIMS/UMLS environment described earlier.

The hospital already has implemented a prototype clinical workstation in which the basic CCSS capability is augmented by the ability to perform miniMEDLINE searches, access a drug information database, and query four systems giving clinical advice (HT-ADVISOR, COAG-ADVISOR, HEPATITIS-ADVISOR, and LIPID-ADVISOR), described later in more detail. For simplicity, the prototype clinical workstation currently runs these decision support programs; future systems will run on a clinical advice server on the hospital network.

OTHER MAJOR COMPONENTS

The prototype information environment includes several other components: a Meta-1 query assistant, topic-based information retrieval, and clinical advice programs, each described here.

A Meta-1 query assistant. In the course of UMLS research, the authors have developed an interactive query assistant that allows a user viewing an online clinical report to initiate a query by highlighting selected words or phrases. (Alternatively, selected terms can be entered manually.) The query assistant automatically helps the user look up each selected term in Meta-1, the UMLS metathesaurus. Using Meta-1, the query assistant can compile a list of all synonyms and related terms to a specified depth of recursion or a list of MeSH equivalents. The query assistant automatically displays the list of terms, and the user then can select terms to include in a search of bibliographic or textual databases.

Topic-based information retrieval. Also during the UMLS research, the authors implemented two systems (HepaTopix in the domain of liver disease, and PsychTopix in the domain of consultation psychiatry) that allow a user inspecting an online patient record to retrieve relevant information automatically [6–7]. To facilitate this retrieval, a conceptual outline of important clinical topics is built into the program.

A list of key clinical topics in a medical specialty provides a powerful link among online information sources, allowing, for example, a focused transition from patient records to a bibliographic database coded using MeSH. The simple translation of terms is neither as useful nor as versatile. When a clinician reads a patient record, a host of relevant clinical issues come to mind, many of which are not mentioned explicitly in the record. This knowledge can be incorporated into the program to facilitate transition between different computer-based forms of clinical information. PsychTopix is in routine use on the Yale Psychiatric Consultation Service. When a resident selects an online written consultation, the PsychTopix search option is presented. PsychTopix will scan the consultation report, offer a tailored list of potentially relevant topics, and upon request perform an automatic MEDLINE search for selected topics.

As described below, the concept of driving information retrieval from a list of pertinent clinical topics is a key feature of the prototype information environment.

Clinical advice programs. During the past decade, the authors have been involved in a series of research projects to develop clinical advice programs [8]. For the past few years, a particular emphasis has been on the development and testing of practical working systems. Programs are operational in the following four domains:

- the pharmacologic management of essential hypertension (HT-ADVISOR);
- the management of hyperlipidemia (LIPID-ADVISOR);
- the clinical interpretation of coagulation test results (COAG-ADVISOR), built using the AI/COAG system as an initial starting point [9]; and
- the clinical interpretation of hepatitis test results (HEPATITIS-ADVISOR).

All four systems are accessible from the wards and clinics of the hospital, running on the clinical laboratory computer. A related project involved the development of the Clinical Advisor Shell, a rule-based program that facilitates the creation of clinical advice programs [10]. This shell has been used to build the four programs mentioned. Programs built in this way are compiled into the C programming language and run on a wide variety of machines, including IBM PCs and clones, Macintosh PCs, Unix workstations, and VAXes.

As described in the following scenario, this shell has been adapted in two ways to allow advice programs to be integrated into the prototype information environment. First, the shell has been adapted to accept input passed automatically from the ISM, in addition to receiving that information interactively from the user. In this way, an advice program need only ask the user for information not already available online. Second, the shell can include a set of clinical topics to be displayed to the user. Associated with each topic is a generic search expression that can be passed to the ISM upon request to retrieve information from diverse information sources.

Figure 3
A simulated screen showing a patient's laboratory test results as they would appear on the clinical workstation

Yale - New Haven Hospital
Clinical Laboratory Report

105-46-02	SHMOE, JOSEPH	54 M		8/27/90
LAB. NUMBER	301	306	403	
MATERIAL	BLOOD	BLOOD	BLOOD	
TYPE	SERUM	SERUM	SERUM	
DATE DRAWN	8/07	8/20	8/27	
TIME DRAWN/REC'D	R13:40	R13:40	R13:40	
CHOLESTEROL, TOTAL	263	300	355	
HDL CHOLESTEROL	60		33	
TRIGLYCERIDES	1100		325	
LDL CHOLESTEROL (CALC)			257	
SODIUM	136	134		
POTASSIUM	4.5	4.2		
BICARBONATE	26	22		
CHLORIDE	103	98		
GLUCOSE	88	122		
UREA-N	16	12		
CREATININE	1.5	1.6		

Figure 4
At the end of its analysis, LIPID-ADVISOR produces on request a list of clinical topics for which further information can be obtained. An asterisk marks those topics that it considers particularly relevant to the case described. For each topic, LIPID-ADVISOR has a stored generic search expression that it can pass to the ISM to allow retrieval from a range of information sources

```
WOULD YOU LIKE TO SEARCH FOR ADDITIONAL INFORMATION REGARDING:


   1.  Hyperlipidemia in the Elderly
*  2.  Association between triglycerides and CHD
   3.  Apolipoproteins and the risk of CHD
   4.  Association between fibrinogen and CHD
   5.  Dietary fiber in the Tx of Hyperlipidemia
   6.  Fish oils in the Tx of Hyperlipidemia
   7.  Estrogens in the Tx of hyperlipidemia
*  8.  Tx of hyperlipidemia in patients with CHD
   9.  Use of probucol in promoting the regression of CHD
* 10.  Hepatitis associated with the use of Niacin
  11.  Cataracts associated with the use of Lovastatin

* The asterisk at the beginning of a line indicates that the selection
  may be particularly relevant to the case most recently described.


Enter selection number, <RETURN> to continue, or STOP/BYE > 2
```

USING THE PROTOTYPE: A SCENARIO

To demonstrate how the prototype works, this section describes a scenario in which a clinician uses the ISM to access a clinical decision support system and then, from that system, uses the ISM again (recursively) to obtain further information from a textual database.

In this example, LIPID-ADVISOR is the decision support system [11]. The clinician is sitting at a workstation looking at a patient's laboratory test results (Figure 3). Noticing that the patient's cholesterol level is high, the clinician wonders about the clinical implications of this test result for the particular patient. By selecting "cholesterol," the clinician requests more information.

Automated linking to LIPID-ADVISOR

The ISM takes this term and displays a list of potentially relevant information sources, one of which is LIPID-ADVISOR. The clinician selects LIPID-ADVISOR.

The ISM entry describing LIPID-ADVISOR includes an input template indicating the information needed about the patient. In this case, the program seeks patient age, sex, total cholesterol, HDL cholesterol, and triglycerides. This input template is passed to the clinical workstation, which fills in the template with available laboratory data. (In the eventual full-scale implementation, the clinical workstation could obtain these values using a PC data transfer package, which downloads data from the central CCSS database.) Thus, any online clinical information is automatically passed to LIPID-ADVISOR.

LIPID-ADVISOR accepts the fully or partially completed template as its initial input and then asks the clinician for any information not online. It then displays all the input information to make sure it is correct and offers its advice regarding the test results.

When the clinician is finished reading, LIPID-ADVISOR offers to obtain further information about relevant clinical topics and, if so requested, produces a tailored list of topics (Figure 4).

Further retrieval from LIPID-ADVISOR

If the clinician is interested in further information about one of the topics, the system then branches out over the network, once again guided by the ISM.

Each clinical topic has one or more associated MeSH terms defining the nature of the topic. Similarly, the ISM entry for each information source contains MeSH terms indicating the contents of that source. By comparing the terms associated with the query (topic) to the terms associated with each information source, potentially relevant information sources are identified automatically by the ISM. The clinician is shown the list of relevant information sources and asked to select those of sufficient interest to access.

Each of LIPID-ADVISOR's suggested clinical topics also has an associated generic search expression. For a selected information source, this expression is translated automatically into a search expression tailored to that source. (In addition to the generic search expression, there also might be a search expression in a particular coding language, e.g., a MeSH expres-

Figure 5
The generic search expression associated with the clinical topic chosen by the user can be automatically translated into a search expression tailored to three different search engines

General Search Expression

```
(and
  (or (specifically medline coronary disease/epidemiology)
     (textword coronary artery disease))
  (or (explode triglycerides)
     (textword hypertriglyceridemia)
     (specifically medline hypertriglyceridemia)
     (textword hyperlipoproteinemia type iv)
     (specifically medline hyperlipoproteinemia type iv)
     (textword lipoprotein lipase deficiency, familial)
     (specifically medline
          lipoprotein lipase deficiency, familial)))
```

MeSH

```
1  all coronary disease/epidemiology
2  (tw) coronary
3  (tw) artery
4  (tw) disease
5  2 and 3 and 4
6  1 or 5
7  explode triglycerides
8  (tw) hypertriglyceridemia
9  all hypertriglyceridemia
10  (tw) hyperlipoproteinemia
11  (tw) type
12  (tw) iv
13  10 and 11 and 12
14  all hyperlipoproteinemia
      type iv
15  (tw) lipoprotein
16  (tw) lipase
17  (tw) deficiency
18  (tw) familial
19  15 and 16 and 17 and 18
20  all lipoprotein lipase
      deficiency, familial
21  7 or 8 or 9 or 13 or 14
      or 19 or 20
22  6 and 21
```

ZYindex

```
(coronary and artery and disease)
and (triglycerides
      or (hypertriglyceridemia)
      or (hyperlipoproteinemia and type
            and iv)
      or (lipoprotein and lipase and
            deficiency and familial))
```

Basis

```
1  coronary artery disease
2  triglycerides
3  hypertriglyceridemia
4  hyperlipoproteinemia
     type iv
5  lipoprotein lipase
     deficiency, familial
6  2 or 3 or 4 or 5
7  1 and 6
```

sion.) Figure 5 shows the generic search expression for the topic chosen by the clinician in this scenario. It then shows how the generic search expression is automatically translated to allow retrieval from MEDLINE and from two textual retrieval search engines, Basis and ZYindex.

In this way, a tailored search can be performed on the chosen information source.

Return to the clinical workstation

Once the clinician is finished, this whole chain of remote system calls unwinds automatically, returning control to the clinical workstation.

This scenario is implemented fully in prototype form on a single Macintosh computer. It is important to emphasize that this IAIMS/UMLS design, with the ISM guiding transition among network-based services, results in a very flexible and dynamic environment. Information sources can be added, deleted, or changed, and as long as the ISM is current, the network communication will continue to work correctly. Linking from LIPID-ADVISOR to a selected information source is dynamic in the sense that the link can be made to any information sources currently described in the ISM. Linking to LIPID-ADVISOR is dynamic in the sense that any program can access the system and will pass on any input parameters listed in the input template of LIPID-ADVISOR's ISM description.

SUMMARY AND CONCLUSION

The environment described in this paper can enhance the information capabilities of an academic medical center. The prototype strategy has allowed exploration of the various desired capabilities as well as demonstration of those capabilities both inside and outside of the institution. Demonstration of various ideas in a working prototype environment has proven valuable in designing a usable system. The next step will involve phased implementation in a distributed fashion on the institutional computer network. This process is in the early stages.

The prototype also illustrates the close relationship between the overall goals of the IAIMS and UMLS initiatives. The IAIMS program addresses the integration of information management at a broad institutional level. The UMLS project addresses many of the same issues at a much more focused level. This paper shows how a prototype developed as part of UMLS research can serve as a pilot model for a broadly based institutional IAIMS effort.

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