A MLM Based Order Entry System:
The Use of Knowledge in a Traditional HIS Application

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Abstract

A new order entry system has been developed on the HELP system utilizing the extensive HELP knowledge base capabilities. Rather than use tables to control site specific characteristics of the ordering system, the new order entry system uses Medical Logic Modules (MLM's) to store and execute site specific features. Using the MLM the user is not only able to set traditional parameters, but enter medical logic to control patient/hospital specific requirements and execute critiquing logic on the order. Simple knowledge editors are provided which make the creation of the order MLM's no more difficult than those programs used to define the site specific parameters of traditional systems.

A major requirement in the design of an order entry system for a Hospital Information System (HIS) is the need for that system to be sufficiently robust to be installed at different sites where each site could impose specific needs to the system. At a minimum these needs might include site costs, special tests, specific departmental data requirements, etc. Additional site requirements are generated when the site attempts to incorporate medical logic in the ordering system. Traditionally, the HIS applications have been designed to provide this site flexibility through site specific tables entered by the user and utilized by the applications. The application programs have generally been written to incorporate in the application code a fixed set of features and functions required by the user and then programmed to access site specific tables for information which when used by the application meets the requirement needs of the site. Incorporation of new features, however, generally requires a rewrite of the programs and update of the information which is stored in the disc based tables. Use of expert knowledge in assisting/critiquing the transactions of the application have normally not been incorporated into the functionality of the applications since maintenance of this logic is beyond the design of traditional order entry applications. Thus, the programs have concentrated on the clerical and administrative tasks of the application and ignored the medical requirements.

Using the knowledge based architecture of the HELP system, a new approach has been taken for the development of HIS applications in general and the order entry application in particular. This approach uses the Medical Logic Module (MLM) rather than a table as the structure for recording the parameters of an order. The MLM is a knowledge representation used to represent modular expert knowledge in a standard shareable format which results in compiled executable code on a target system. This form of knowledge representation is currently under development as a standard for sharing knowledge between centers and represents the thinking of several centers in the creation of ways to share the research being done at those centers. Use of the MLM as the structure for recording site specific information for the order adds several new capabilities to the site for creation/execution of the order. Traditional systems which provide tables are limited to the control of procedure codes, ranges, or special parameters which may have been incorporated into the ordering model by the designer of the system. With the MLM, because of its knowledge structure, the user cannot only adjust the order parameters controlled by the basic design of the system, but add any logic statements requested by the user. A classic example of this is illustrated in medication ordering. Under classical systems the user may define the site specific formulary and for each medication in the formulary set its appropriate dose ranges, routes, and schedules. These systems may also have incorporated some drug - drug interactions, but the user is unable to add any other alerting/critiquing knowledge to the order. With the MLM as the model for incorporation of site specific information, it naturally allows the user after entering in the dose range, route and schedule, to easily add any alerting/critiquing logic which may be appropriate for their site. The logic added by the user is not restricted to only drug-drug interactions, but may incorporate logic using any of the data elements stored in the patient record. Because of knowledge editors provided for creation of order specific MLM's, the user in creation of the MLM's enters the logic and parameters using a program of no more complexity than that provided by traditional table based systems in the setting of the order parameters. A second advantage of the MLM approach is the run time execution of relatively simple compiled code rather than execution of a more complex program which must at run time read the appropriate tables and from those tables decide at run time the appropriate logic to be executed. Finally, because the system is executing MLM's, it may invoke MLM's which have been developed for other applications and reside in the MLM knowledge base. Likewise, the MLM's created for this application may be used by other applications where appropriate. For example, the check of the medication order against laboratory values may be used in the background to monitor laboratory values as well as critique the medication order.

Figure 1 outlines the basic HELP system architecture used to execute the MLM's. As seen in the figure the HELP system consists of a patient database, a knowledge base consisting of MLM's and application specific managers which serve as expert inference engines which access MLM's in the knowledge base. Under this architecture an application manager can access any MLM which exists in the knowledge base and any MLM can access any other MLM. The main purpose of the application manager is to control the navigation to the appropriate MLM's and serve as a global

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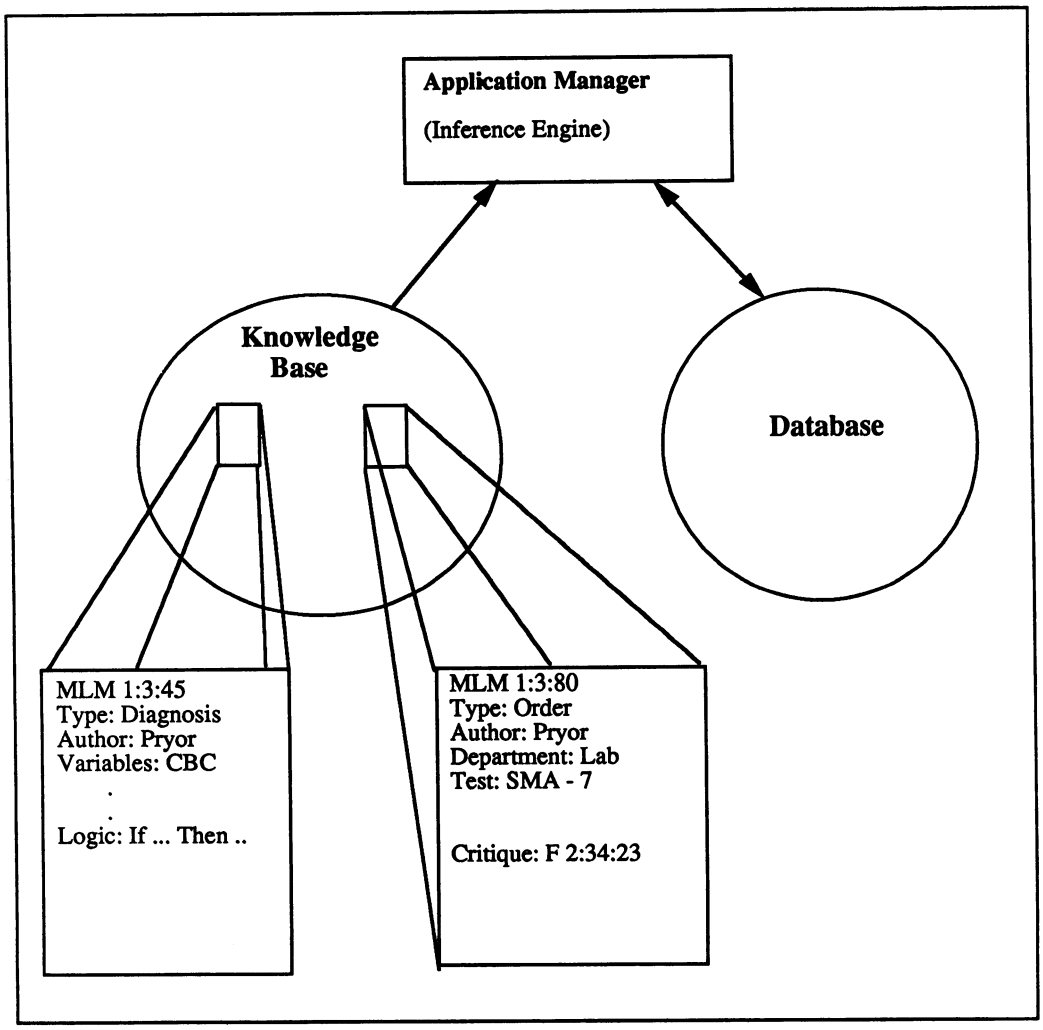

Figure 1
Architecture of HELP Application Programs

memory for the application. In so doing, its memory serves as the blackboard for the MLM's accessed during a transaction. The MLM's in the knowledge base are accessible by any application manager and therefore exist independent of any particular application. With the modularization of the application, the expert can easily manage the knowledge(MLM's) through knowledge editors provided by HELP. MLM's have traditionally been available in HELP to provide alerting, critiquing and management decisions. These decisions, both data driven and user interactive, have been one of the important features of HELP.

In development of the MLM based order entry application, extensive use of the HELP architecture was required. The major use was to model each type of order as a knowledge frame. That is, it was necessary to design for clinical laboratory tests a MLM structure, for xray orders a separate MLM structure, etc. Within each MLM structure slots were defined to incorporate the necessary knowledge for the type of order. While structures are different for each type of test it is easier to illustrate the system by considering a single class of orders. Figure 2 illustrates the MLM structure used in defining a clinical laboratory test order. The first slot **Test** holds the name of the test actually being ordered. The next 9 slots describe the information needed to complete a laboratory test order. These slots include the order priority, specimen type, order start and discontinue time, etc. When these slots are instantiated they will contain default information that will serve as the initial suggestions to the parameters needed to complete the order. The next slot **Patient Specific Knowledge** is used to store a reference to another MLM where logic would exist to modify the default parameters of the test order. Execution of this MLM may result in modification of the order based on logic evaluated from data in the patient record. Logic within this frame can additionally perform administrative and/or clinical checks. This slot is optional if no patient specific frame has been developed for this order.

The final slot **Critiquing Knowledge** contains a reference to a MLM used to critique the order. This frame is executed after the user has reviewed and accepted the order. Following the execution of the critique a message/alert could be transmitted to the user indicating need for modification of the order. The message/alert may also be sent to another application on HELP. Again, this slot is optional in the frame and is included only when a critiquing MLM has been written for the specific order.

Test: <The test to be ordered>

Department: <The department receiving the order>

Priority: <The priority of the test>

Frequency: <Number of times order is to be repeated>

Start Time: <Date when series order is to begin>

Stop Time: <Date when series order is to be discontinued>

Available: <Availability of specimen>

Specimen: <Specimen type on which test is to be performed>

Location: <Location where report is to be sent>

Comments: <Comments>

Patient Specific: <MLM containing patient specific knowledge>

Critique: <MLM containing critiquing knowledge>

Figure 2
Definition of the MLM for Clinical Laboratory Orders

For other classes of orders different slots would be required. Common, however, to all models are the **Patient Specific Knowledge** slot and the **Critiquing Knowledge** slot. For example, the xray order may require a **Transportation** slot and a **Special Handling** slot as a part of the model for ordering the xray, but would still have available the **Patient Specific Knowledge** and **Critiquing Knowledge** slot. Design of the system is really design therefore of the models for each class of order.

Using this MLM model, an MLM is instantiated for every possible order which could be made by the system. Figure 3 represents an instantiated MLM for a PTT order. The instantiated MLM contains information which might have been included in tables used in traditional design and the references to the expert logic modules which will be processed at the time of execution of the order. The figure illustrates logic that might be contained in the Patient Specific and Critiquing MLM's for that order. To create the set of instantiated MLM's an order knowledge editor has been written. The editor allows the expert/knowledge engineer to create an order MLM. In creating/editing the MLM the user sets the default slots and enters the references to the Patient Specific MLM and the Critiquing MLM. On completion of the editing, the MLM is compiled for use in the system. This has the effect of creation of a small compiled program which is designed to have the functionality necessary for the ordering application. That is, it will include within the compiled MLM data presentation logic, data entry logic and procedural logic necessary for execution of the MLM on the HELP system. If any of the procedural presentation logic requirements change, each of the MLM's are recompiled by the modified knowledge editor to incorporate the current requirements. Since the expert defined knowledge is contained in the MLM it need not be reentered at the time of recompilation. The addition of the presentation, data entry, and procedural knowledge to the compiled MLM ensures that each MLM will be implemented in a common manner throughout the system. This knowledge is contained in the knowledge editor and is key to the success of the system. This knowledge determines how the MLM is presented to the user and controls the performance of the system. The procedural knowledge entered by the editor will interface the execution of the MLM to the architecture of HELP. We are currently exploring the use of a commercial application generator to assist in the creation of the knowledge editor.

The final MLM needed for implementation of the system is the order manager module. This module is written using the HELP PAL language rather than the knowledge editors due to the extensive use of procedural information contained in the application manager. It controls the use of the test specific order MLM's and permits easy navigation to supporting functionality. Control of the test specific order MLM's occurs upon entry into the order manager. The user is asked to enter a mnemonic identifying the test to be ordered. This mnemonic is used as a key to link to the appropriate order MLM. The order manager is responsible for transmitting to the order MLM any global information/parameters necessary for proper execution of the order frame. Navigation to supporting functionality, such as changing patient id, review of patient orders, or review of patient data is facilitated in the order manager. At any point in the ordering process the user can request, via a function key, to be transferred to a supporting function. These supporting functions are in fact other MLM's which have been written to support that particular function. The order manager is responsible for transmitting relevant information, such as the patient's name, to the MLM responsible for the supporting function. The manager will also retrieve relevant information from the MLM executing the supporting

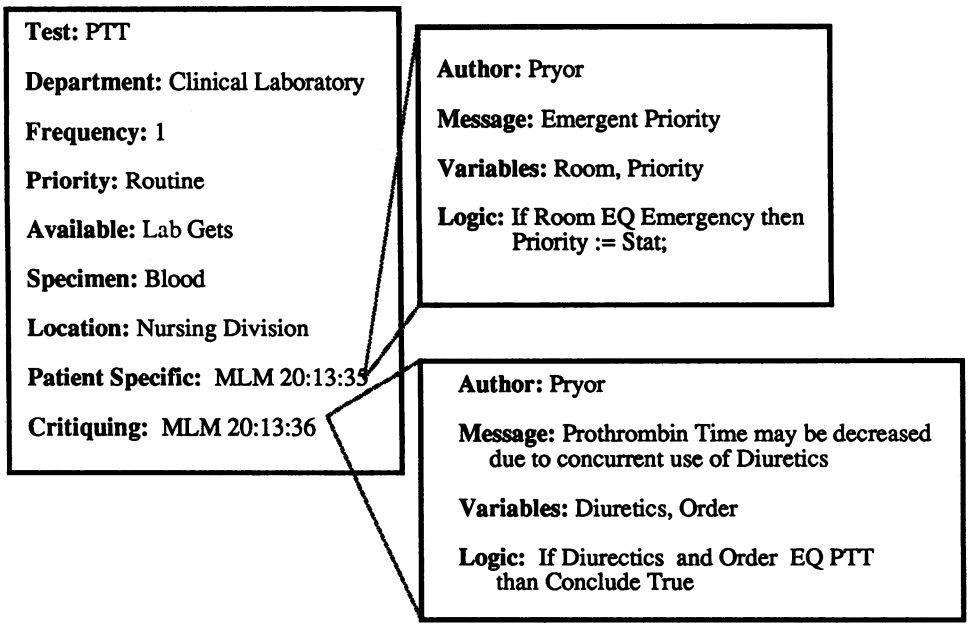

Figure 3
Example of an Order MLM and
its Associated Logic MLM's

function. In the case of reviewing patient orders, those orders chosen by the user for reorder would be retrieved and used to establish initial defaults as well as provide the link to the appropriate order MLM. The manager holds all orders for a user session. It permits modification of the orders within a session and allows storage of the orders at anytime within the session. Once the orders are stored, the interface programs of HELP transmit the orders to the appropriate departments for execution and generation of the billing transactions for use by the financial system.

Because of this unique architecture, the ordering system can easily invoke the logic MLM's which contain both patient specific, critiquing, and alerting knowledge. Since the MLM can contain logic covering all aspects of the HELP system the knowledge incorporated into the MLM can contain knowledge/rules specific to the patient, the test or the doctor who requested the order. Specific site controlled administrative logic could be just as easily incorporated into the MLM as patient specific knowledge. A simple example of patient specific logic would be changing the priority of the order from routine to stat when the patient was located in the emergency room. In this example the Patient Specific MLM checks the room location and if the patient is in an emergency room, it changes the priority of the order to stat and returns to the order frame. An example of administrative knowledge which could be easily entered could be transmission of the blood sample to the appropriate location for analysis dependent on patient location, time of day, etc. An example of knowledge in a Critiquing MLM for ordering a laboratory test would be to check the medications which the patient is taking and alert the user if one of the medications could interfere with the results of a laboratory test. If such an interference was noted a message could be sent to the user suggesting discontinuance of the drug or awareness of the potential interference which could cause in the results of the test. If the drug were not discontinued, the interference alert could then also be displayed at the time of review of the results of the laboratory test. Other examples include knowledge of adverse reactions to some dyes used in xray procedures, awareness of patient data which may be crucial to the ordering process, suggestions of more cost effective tests to accomplish the same function, etc. The power of the system really comes in the use of the knowledge which could be written and evaluated at the time of execution of the order.

Currently the system as described here works only with single orders. Modeling is now underway to extend the MLM structures to include order sets. Order set models are being developed based on both ordering physician and patient problem. Models involving order sets will be extended to include set logic which can determine dynamically which orders in the set are appropriate at a given order session. By incorporating into an ordering system the type of knowledge discussed here, we feel that the system will have greater benefit to the physician. Traditional ordering systems have not been well accepted by the physician since they primarily are only clerical in their functionality. We believe that through the introduction of knowledge in the ordering process, we will provide to the physician a tool to enhance his management of the patient. This process linked to the other decision modules of HELP should provide us with a system which is perceived by the physician as a tool which assists him/her in the care of the patient rather than require him/her to become a clerical person.

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