Optimizing Physician Access to Surgical Intensive Care Unit Laboratory Information through Mobile Computing

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Approximately 30 minutes of computer access time are required by surgical residents at Stanford University Medical Center (SUMC) to examine the lab values of all patients on a surgical intensive care unit (ICU) service, a task that must be performed several times a day. To reduce the time accessing this information and simultaneously increase the readability and currency of the data, we have created a mobile, pen-based user interface and software system that delivers lab results to surgeons in the ICU. The ScroungeMaster system, loaded on a portable tablet computer, retrieves lab results for a subset of patients from the central laboratory computer and stores them in a local database cache. The cache can be updated on command; this update takes approximately 2-7 minutes for all ICU patients being followed by the surgeon, and can be performed as a background task while the user continues to access selected lab results. The user interface presents lab results according to physiologic system. Which labs are displayed first is governed by a layout selection algorithm based on previous accesses to the patient's lab information, physician preferences, and the nature of the patient's medical condition. Initial evaluation of the system has shown that physicians prefer the ScroungeMaster interface to that of existing systems at SUMC and are satisfied with the system's performance. We discuss the evolution of ScroungeMaster and make observations on changes to physician work flow with the presence of mobile, pen-based computing in the ICU.

INTRODUCTION

Laboratory information is one of the mainstays of managing the critically ill patient. An estimated 40 percent of patient-care decisions in the intensive care unit are guided by laboratory values and trends alone [1]. In the typical hospital, the surgical team's access to laboratory data from the hospital information system can be compromised. Patient care is provided in diverse locations. Even when bedside terminals are available, the time required to log in, search, and retrieve laboratory values can be prohibitive given time constraints on the physician. Large patient services (e.g., 10-30 patients) or complex patient cases (e.g., critical care patients) provide physicians with challenges to lab retrieval and lab results awareness. Physician knowledge of lab data can be incomplete or out-of-date, and patient care may be delayed.

Motivation

Medical centers use a technique called "rounding" to verbally present information to all members of a medical or surgical team. To prepare for this process, physicians "pre-round", gathering subjective and objective information while performing care activities on their patients. At SUMC, pre-rounding involves going to a nursing station or bedside computer, logging on, requesting and viewing the lab values, and manually transcribing them onto paper. Each physician develops her own method to record this information, resulting in an idiosyncratic but time-consuming note taking system. Physicians must look at the values, transcribe the important ones, and sometime take immediate action.

An alternative to this transcription process is to provide the surgical team with automated laboratory information retrieval that presents laboratory test results. We hypothesize that a mobile, pen-based computer system with a specialized graphical user interface (GUI) tailored to its users can permit faster and more convenient access to laboratory test results than conventional paper-based or fixed desktop computers.

SYSTEM FEATURES

The *ScroungeMaster* system is a software program designed to optimize the retrieval of lab information by knowing about patients and physicians on a surgical service. Implemented features of the system include:

- rapid, accurate, secure, and reliable access to laboratory data on a mobile computer system,
- lab test results organized into nine physiologic systems (cardiac, endocrine, renal, etc.) that minimize pen "taps" and "scrolling", and
- context-sensitive presentation of lab data driven by physician preferences, viewing trends, and tracking of physician lab-retrieval activities.

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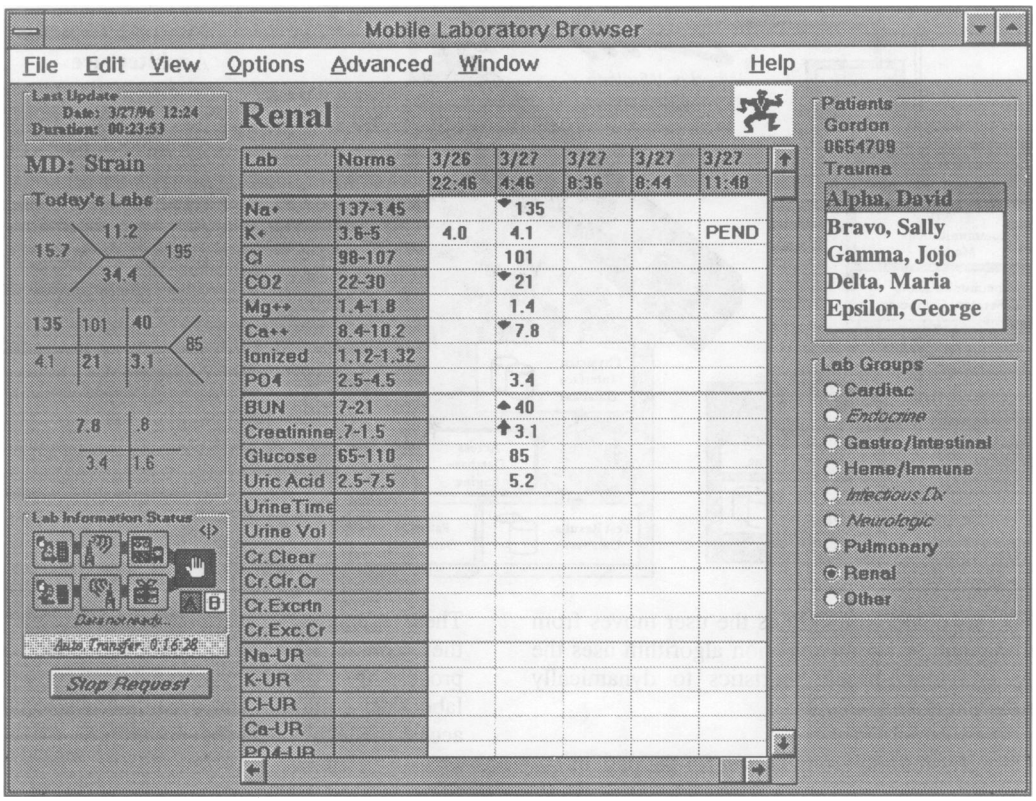

Figure 1. Display Physiologic Groups

The main ScroungeMaster screen in the process of a data retrieval is shown. From left-to-right, a synopsis of today's labs, network and retrieval status, the labs for the Renal group, a personalized patient list, and controls to change between lab groups are displayed. Group names in bold indicate the presence of data in that group. Selecting a patient or lab group is done by "tapping."

SYSTEM DESCRIPTION

Application

Software was created on Windows for Pen Computing 1.01 and Windows 3.1 Operating Systems using Visual Basic 3.0 software, Microsoft Access 2.0 Database software, and Trumpet Windows Socket routines for Transmission Control Protocol/ Internet Protocol (TCP/IP). Distinct Visual Basic Controls provide application layer access to network connectivity.

Hardware consists of a 486-based mobile computer (IBM ThinkPad 730T), an Ethernet III PCMCIA LAN card and a 10-BaseT network connection. A dedicated "base station" server (IBM PS/ValuePoint 486 DX2 computer) is connected to the HIS.

ScroungeMaster's laboratory information is maintained by the hospital laboratory computers (two Data General MV9600s) at SUMC.

Graphic User Interface

Lab tests by physiologic groups are displayed in grids showing all results for a user-selected period (Figure 1). Grids can be customized by the user for their content and the order of lab tests in them. Currently, 1100 lab studies are available through ScroungeMaster, including all labs at SUMC except blood gas, microbiology, and culture results.

Patient selection is performed by tapping on the patient name. The list of patients is maintained by users, and lab retrievals are limited to patients on this list. The user interface also displays network status, displays "alert icons" for out-of-range values, and provides several methods for viewing data: by physiologic group, by "tabular" display of all patient data in a single window, and by graphing of selected lab data for better appreciation of trends. Login is required at startup to allow access to patient data and automatically configures these user display preferences.

In the presence of large volumes of data, getting to the salient items quickly can be difficult. ScroungeMaster models the user's context of viewing lab data and re-

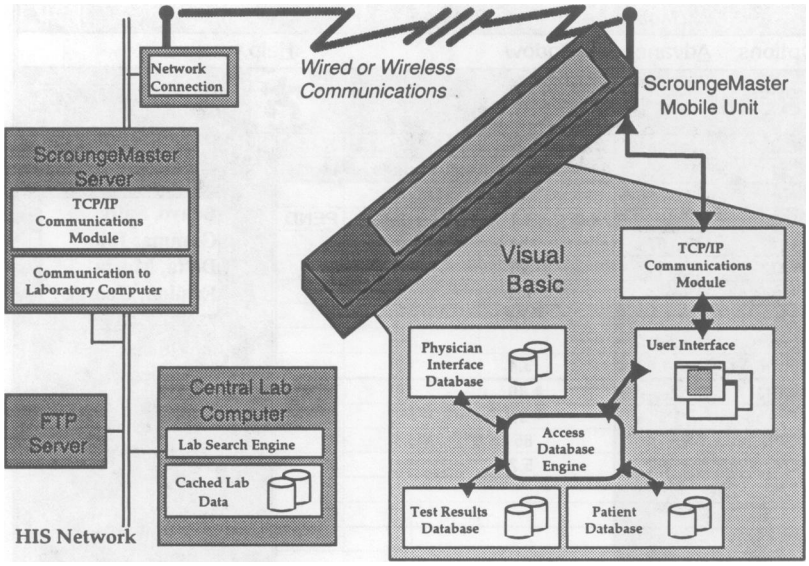

Figure 2. Systems Architecture
Mobile units are connected to the hospital network to access the lab computer. They can either request a new lab retrieval via a Telnet session or import via FTP the latest pre-cached version of the data that has been created by the ScroungeMaster server and stored on the main lab computer.

establishes this context quickly as the user moves from patient to patient. A layout selection algorithm uses the following preference-based heuristics to dynamically organize the interface elements:

1. The last physiologic group shown for the patient.
2. Resident physician preference (e.g., a physician preferred to see Cardiac data first)
3. Attending preference (e.g., the chief ICU surgeon uses total bilirubin levels to measure organ dysfunction and therefore examines Gastro-Intestinal group labs preferentially)
4. Default preference by patient type (e.g., for post-operative patients, show Hematology group to check on post-op bleeding, etc.).

Retrieval Protocol

Two modes of retrieval are provided: standard retrieval and a faster retrieval using pre-cached data (Figure 2). In initial testing lab requests followed a cyclical pattern—users were able to anticipate when labs were going to be needed. A server computer was installed with an automatic retrieval module controlled by the mobile units. Users define a retrieval schedule and the server pre-caches lab results, storing them on the legacy system.

In a standard request, mobile units generate a "query" using a database of laboratory codes and the patient list. A file transfer protocol (FTP) transmits this query to a search engine resident on the central laboratory "legacy" computers. A Telnet session initiates the retrieval. Lab results from any request return as a structured text using FTP. Support files (e.g., patient lists, data backup, database cache) are maintained on the legacy computer. These synchronize and update the mobile units when they contact the legacy system. Transaction-based processing is used for communication with the main laboratory computer and permits multiple client units to access the legacy data sequentially.

CONVENTIONAL VS. AUTOMATED RETRIEVAL

Important distinctions must be made between conventional and ScroungeMaster retrieval for the observations and analysis that follow. After manually transcribing lab results in the classical lab retrieval approach, a physician has seen those labs at least once. Patient care actions also may be performed as data is reviewed (e.g. change intravenous fluids after observing an abnormal value). It is difficult to separate retrieval times from other patient care tasks in evaluating conventional lab retrieval. ScroungeMaster, on the other hand, effectively automates the transcription process so that once done, the physician still has not seen all the lab values. Although the user may be performing other patient-care tasks during an automated retrieval, examination of recent lab data cannot take place until after the retrieval is complete. Conventional and ScroungeMaster retrievals are discussed below in the knowledge that direct comparison of the techniques may not be appropriate.

EVALUATION METHOD

Evaluating Retrieval Practices

A 38-item questionnaire to ascertain usual lab-result retrieval practices and surgical patient-care work flow at SUMC was given to all surgical housestaff and attendings prior to deploying ScroungeMaster in the hospital. Subsequently, the surgical ICU team was

observed and filmed on rounds to document their pre-implementation work flow practices. Conventional lab-retrieval activities were timed and documented.

Evaluating the Application

Timing and accuracy studies were performed with the prototype and a one-hour training session was given to all users. During the first two weeks a physician-observer-researcher (JS) was present for all "rounds" by the service and 24-hour technical support. The next two weeks the surgical team used the system without the presence of the researcher. A series of trials following the above protocol has been initiated with subsequent surgical ICU teams.

OBSERVATIONS

Six weeks of deployment in the ICU has been completed. Data collected by ScroungeMaster software was augmented by questionnaire results, researcher observations in the ICU, and verbal evaluation of the application by the users.

Speed of Access to Information

Selected questionnaire data is displayed in Table 1. While questionnaire research estimated a mean of 40 minutes/day for lab in the non-mobile setting, the physicians studied were not covering only ICU services. Retrieval times seen by filming and researcher observation in our study are probably more accurate for the ICU population. We observed "rounds" on five consecutive days in the ICU. Rounds lasted an average 49 minutes (min=37, max=70) with 2-7 patients on the service. "Pre-rounding" by 2 residents required 30 to 45 minutes using conventional lab retrieval.

ScroungeMaster "pre-round" retrievals using pre-cached data averaged 2-7 minutes (SD = 2.22) for all patient on the service. The physician's then used the cached data for directing patient care and presentation on rounds

Researcher observation of retrieval events by residents suggests that our display was successful at minimizing navigation tasks to one or two "taps." Switching between patient records in ScroungeMaster requires approximately 9 seconds, while changing between physiologic groups requires 0.5 seconds. Questionnaire data suggests that conventional retrieval systems average five clicks to perform similar tasks and are associated with more login events (Table 1). Residents found the ScroungeMaster startup and login processes slow (30 seconds), but were pleased with the quickness of changes between physiologic groups.

Layout Algorithm

Surgical residents (four users) stated that they found the layout algorithm helpful in that it re-established the clinical context of what physiologic problem had been examined last. Residents reported that searches for laboratory information (e.g., on request by a senior physician) were simpler and more intuitive on ScroungeMaster as compared to conventional systems.

Surgical Work Flow

We observed a number of changes in physician behavior once ScroungeMaster was introduced into the clinical environment. Previously, dictation of progress notes required physicians to examine hemodynamic data on monitors by the bedside, then move to a separate terminal to view lab data or interrupt their dictation to request lab values from other team members. The mobility of the ScroungeMaster tablet allowed the attending physician to dictate the entire progress note at the patient's bedside. In two instances, lab results not normally transcribed because of delays in the time for the lab study to be processed were located using our system because ScroungeMaster routinely retrieves lab results from the preceding five days. Finally, the ability to silently pass the unit between team members minimized interruptions during morning conferences.

Comments by Users

The ThinkPad 730T computer was described as "light" and "bulky", with an acceptable LCD backlit screen. Battery life was estimated at two hours between charges. While users noted inconvenience associated with travel to the 10-BaseT connection (centrally located at the nursing station), the inclusion of Netscape, access to

Table 1. Questionnaire Data

A Description of Surgical Services and a Subjective Analysis of Lab Retrieval Activities

	Patients on Surgical Service	% of Patients in the ICU	Minutes/Day on Lab Test Retrieval	Times per day access computer	# clicks to access a lab test values	Minutes in preparation for each "rounds"	% of time have to call lab for value
# Physicians Responding	16/20	16/20	16/20	16/20	16/20	17/20	16/20
Mean	12.9	22.8%	39.7 min./day	3.6 times/day	5.3 clicks	16.9 min.	21.6%
Std. Dev.	6.99	25.28	24.73	1.71	1.83	7.98	17.60

Data on 20 surgical residents, Stanford University Hospitals, 1/95

Residents for this study were working at the Stanford University Medical Center or it's affiliates. They were asked to describe their surgical service and estimate the times required for various activities based on the previous month's surgical rotation. Multiple surgical services and specialties are represented in this dataset.

Medline, e-mail, and Microsoft Office products were incentives to using the system.

DISCUSSION

Studies suggest that 30 percent or more of a physician's time is invested in performing routine information-gathering tasks [2]. Nykanen suggest that this trend in medical care has moved the clinical diagnostic process from a "problem-oriented to a data-oriented one" [3]. The question remains as to how the physician can better function in this milieu.

Poon suggests that medical information can best be searched by maintaining "positional constancy" of the data [4], and we implemented this as part of our GUI. The rapid training times (10-15 minutes), the minimal pen taps to reach a lab result, and the hesitancy of the users to alter physiologic grids (i.e., only two lab tests -- TRH and Lactic Acid --have been moved in six weeks of use) seem to support this paradigm.

Other authors state that "graphical display of lab data can be interpreted faster and more accurately than a column of numbers"[3]. Although it is early in the evaluation and may be an artifact of our implementation, the tracking log shows minimal use of ScroungeMaster's graphics display mode (i.e., < 10 times/month/user). While research does show the advantages of graphical displays for many environments, it may be that at a certain threshold of complexity (as seen with ICU lab data) the grid-style display provides less confusion, and, consequently, a better viewing mechanism. This has been observed with other pen-based, mobile applications for use in hospital [5, 6].

Analysis of the software paradigm

While automatic laboratory information retrieval may be desirable, many attending surgeons at SUMC suggested that manual transcription events are beneficial, helping the resident to "process" the patient case. In our study, residents were observed to combine conventional lab retrieval with calls to nurses to change intravenous fluids or to re-order labs. Our paradigm provides markedly increased rates of retrieval for lab values, but we have not yet ascertained if this adversely affects lab utilization by the surgical team in the ICU.

FUTURE PLANS

Trials of wireless retrieval have been performed using Proxim RangeLAN II and Xircom wireless networks. Performance characteristics of ScroungeMaster over a 1 Megabit wireless network (e.g., Xircom) are very similar to those of the standard 10-BaseT connection and pending approval of the wireless technology by SUMC Engineering, we plan a trial of wireless access in April 1996. We are designing a formal evaluation of the tracking log to obtain qualitative and quantitative data on navigation within ScroungeMaster and examining the use of "attending satisfaction" as a measure for the effectiveness of conventional vs. ScroungeMaster approaches to "pre-rounds" preparation. Finally, a follow-up questionnaire will be completed by residents at the end of their ICU rotation to document perceived changes in post-implementation lab retrieval tactics.

CONCLUSION

Our research supports that a mobile, pen-based computer system can permit fast and convenient access to laboratory test results. Initial evaluation suggests that these goals can be met through a graphical user interface constructed expressly for the needs of our surgical resident users and incorporating a layout algorithm governed by user preferences, patient medical condition, and previous lookup events. Further evaluation is required to demonstrate that the ScroungeMaster approach is more effective than conventional hospital laboratory access systems.

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