Published in European Journal of Operational Research (special issue after HCP'2003), in press

Designing Man-Machine Interactions for Mobile Clinical Systems: *MET* Triage Support using Palm Handhelds

Wojtek Michalowski*
University of Ottawa
Marta Kersten
Queens University
Szymon Wilk
Poznan University of Technology
Roman Slowinski
Poznan University of Technology

Abstract
The **M**obile **E**mergency **T**riage (*MET*) system is a clinical triage support system that aids physicians in making triage decisions as to whether a child presenting in the Emergency Department of a hospital with a specific pain complaint should be discharged to the family physician, needs to be admitted for further investigation/observation, or requires urgent specialist consult. The system's mobile component is designed to work on a Palm handhelds. This paper presents our experience and discusses some of our original solutions with regards to designing man-machine interactions for mobile clinical support systems. Specific interactions adopted in the *MET* design that are discussed in the paper were created in consultations with potential end users and tested at the Children's Hospital of Eastern Ontario in Ottawa.

Keywords: mobile devices, Palm handhelds, clinical triage support, emergency triage.

Introduction
The **M**obile **E**mergency **T**riage (*MET*) system is a computer-based clinical support system that aids emergency personnel in making a triage decision as to whether a given patient

(1) Should be discharged to family physician,

(2) Needs to be admitted for further observation, or

(3) Requires urgent specialist consult.

The MET system is developed in a modular way, with each module designed to deal with specific acute pain condition. Thus, the system can be easily modified by replacing existing modules or by adding new ones.

The *MET* mobile component is implemented on a handheld device running PalmOS. *MET* users, namely medical residents and Emergency Department (ER) physicians, enter data into the handheld about a patient's history, his/her physical examination, and/or the results of tests. The system has a triage function that allows a user to consult a rule-based decision model in order to get a triage recommendation. This function can be invoked at any time in the triage process, irrespective of the amount of information about the patient's condition that is currently available. The system not only

* Corresponding author. *MET* Research Team; School of Management University of Ottawa Ottawa, Ontario K1N 6N5 Canada tel.+1 613 562-5800 x.4955 wojtek@management.uottawa.ca

helps in making triage decisions but also contributes to improved management by allowing doctors and residents to collect data in a structured way.

MET is designed to work in an ER environment. Due to the significant space limitations of most the Emergency Departments, use of a desktop computer in such an environment is not a feasible option and hence a handheld, that is compact and mobile device, was selected. Mobility of a computing device is a significant advantage in terms of system's accessibility, but adds to the complexity of a design. Drawbacks such as small screen, limited number of fonts and colors, and restrictive data entry format place new requirements on the design specifications and quality of man-machine interactions. Some design guidelines, especially those related to domain specific and user-centered interactions were applied while designing *MET* (Gulliksen, 1996; Gulliksen and Sandblad, 1995; Weinger, 2000). However, lack of well established and tested design principles combined with the scarcity of research on standards for mobile devices, made our work both novel and challenging.

The paper is organized as follows. In the next section we discuss basics of man-machine interactions in medical domain. It is followed by a presentation of solutions that were implemented in the *MET* system and we give the rationale behind them. The paper ends with a discussion.

Man-Machine Interactions in Medical Domain

Well-designed interactions are essential in computer systems developed for medical domain because the cost of potential flaws can be enormous. Notwithstanding such requirement, many interfaces in medical/clinical systems "are poorly designed, fail to adequately support the clinical tasks for which they are intended, and frequently contribute to medical error" (Weinger, 2000). Possible reasons for this situation include:

- Lack of the ability to field test the interactions framework outside the application context (namely the operating room, the ER, ambulance),
- Discontinuity between a development effort and end-user requirements.

Due to a nature of the application domain (clinical environment) and work pressures on the end-users, it is very difficult to develop a controlled clinical trial to evaluate the interactions framework. This is specially true for the ER environment where nature of work and constant time pressure on the health care providers do not create testing opportunities that are available for business applications. Such a situation leads to a phenomenon that is well documented in the Information Systems literature, namely a lack of congruence between design specifications and end-user expectations, further amplified by a fact that the analysis stage of the system design is for practical considerations curtailed due to the reasons outlined earlier. In order to address these reasons Wiklund (1998) proposed to adhere to specific principles while designing man-machine interactions for medical devices. These principles come mainly from the software engineering research, thus a design framework proposed by him aims to improve the typical interactions by eliminating information and control overload, eliminating the liberal use of colors in a manner that is inconsistent with medical conventions, and by allowing easy navigation within the system's components.

The importance attached to well-designed and no ambiguous man-machine interactions in medical domain amplifies need for domain-specific and user-centered design of them (Gulliksen and Sandblad, 1995; Gulliksen *et al*., 1993). This implies, on one hand, understanding of human behaviour in terms of task execution, reasoning, problem solving and interpreting, and on the other hand, development of a "clean" interaction framework. Such a framework should allow end-user to focus his/her attention on the tasks to be supported through enhancement of his/her cognitive abilities. This should be accomplished by use of domain-specific metaphors and eliminating end-user's need to be concerned

Published in European Journal of Operational Research (special issue after HCP'2003), in press

with the operation of computing device. While there are some general frameworks enforcing such an approach, they were not developed with a handheld computing on mind. In the following section, we will describe how through research and extensive experimentation we were able to develop specific interaction solutions for mobile triage support system.

MET **Man-Machine Interactions**

The *MET* system design (presented in Figure 1) follows general principles of a client – server architecture, with the server being responsible for management of the databases (database subsystem), synchronization of the clients (sync subsystem), and decision model calibration (model subsystem). The mobile client component implemented on Palm handheld is used for entering information about a patient's condition and for invoking clinical algorithm for recommending triage. The Web-based client component that could be executed on a stationary computer connected to the Internet or Intranet, has the same functions as a mobile component with additional capability of managing patients' data that is used/generated by a mobile component.

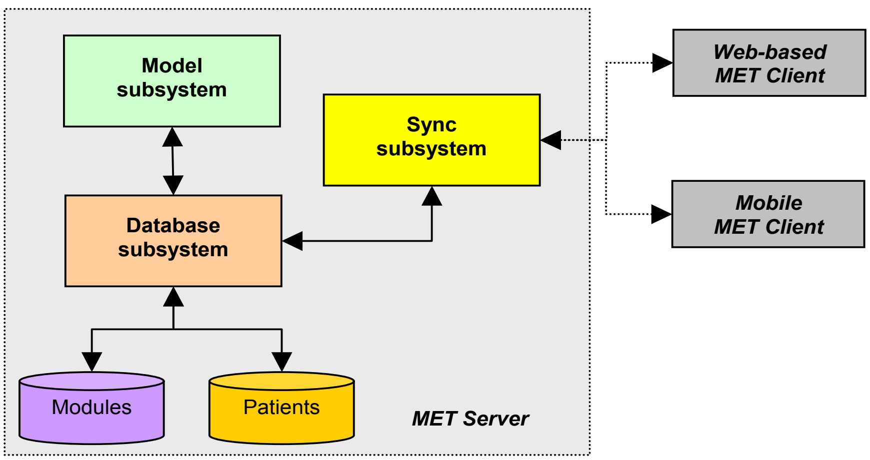

Figure 1. *MET* architecture.

The mobile *MET* client that is discussed in this paper was developed according to object oriented principles and its design blueprint is illustrated on Figure 2.

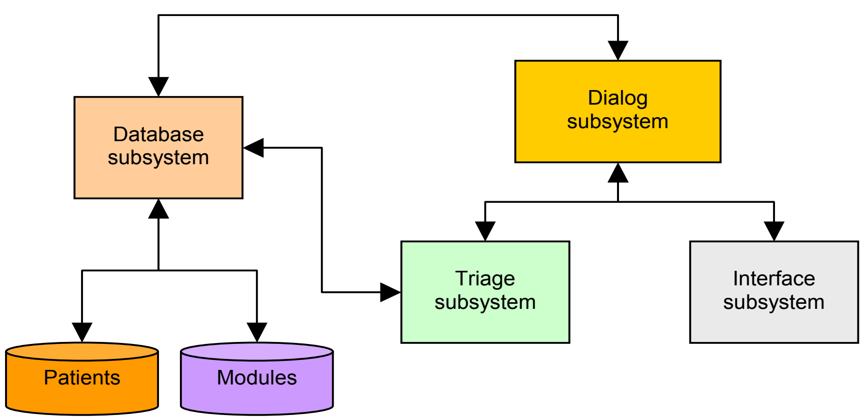

Figure 2. Mobile *MET* client architecture.

For the purpose of this paper, only the *dialog* and *interface* subsystems are of an interest. The role of *dialog* subsystem is to manage man-machine interactions according to the embedded principles that specify the sequence of displaying appropriate screens associated with individual symptoms and signs, and prescribe system's behavior in response to end user's action (e.g. tapping a button). The *interface* subsystem is a repository of interface elements (building blocks) that are used by the *dialog* subsystem to interact with the end user. These blocks include: screens common to all clinical modules (e.g. login screen, list of patients, *etc*), general screens customized for the particular module during the run-time (e.g. history or report screen), and editors, i.e., tools used for editing values of the clinical features (pictograms, check boxes, lists).

In developing the framework for man-machine interactions in the *MET* mobile component, the following domain and user-specific principles were followed:

- Keeping the overall interactions transparent, simple, and clean,
- Making efficient use of the display,
- Eliminating data entry using graffiti system,
- Contributing to the accomplishment of the task at hand by using cognitive clues.

It is clear that cognitive needs associated with a specific application domain should play a paramount role while designing interactions aimed at a particular work environment (Gulliksen *et al*., 1993). The *MET* system is designated to be used in the ER environment, and any obstruction of the task at hand caused by the system would simply make it unusable. The ER medical personnel will be consulting the *MET* system while performing tasks under pressure, when the need to use a computer is often perceived as a hindrance. Thus, one of primary objectives was to develop such a system that does not deter medical residents and physicians from routine patient management. Consideration of the intended user group, the way in which its members perform tasks and what type of systems they are accustomed to were very important factors when deciding about specific solutions. The users of the *MET* system were more familiar with clinical activities, filling out patients' paper charts, and administrating tests than with scrolling and navigating through screens, tapping buttons, and writing graffiti. In order to facilitate their interactions with the *MET* mobile component, symbols that are familiar to the end-users, such as check boxes, thermometers, body pictograms, icons with well-known cues (e.g., microscopes), and labels used within the hospital were incorporated as the main design features. They were combined with intuitive navigation between different system elements and complete elimination of the use of graffiti and textual data entry.

Navigation

The main concept behind managing navigation between different *MET* functional elements was to focus on four main activities associated with triage: getting a patient's history, conducting physical examination, evaluating test results, and triaging a patient. Correspondingly, *MET* has four main screens - one for each activity. Selecting an icon associated with a given activity invokes *MET* element for that activity (see Figure 3). The icons are subsequently repeated (in smaller format) on every *MET* screen thus enforcing a cognitive image of each of the activities, and allowing the end-user to move easily throughout the system functions (see Figure 4).

Published in European Journal of Operational Research (special issue after HCP'2003), in press

Figure 3. Main triage activities.

Figure 4. History screen.

Icon Based Models

There are good reasons behind the use of icons in *MET*. The first being that small icons at the bottom of each screen require less screen space then usual navigational buttons, such as ‘next’, ‘back’ and so forth. Also, use of graphical symbols enhances man-machine interactions, as suggested by Wiklund (1998). Deriving at specific graphical icons used in the *MET* system was an interactive process characterized by numerous consultations with the ER physicians at the Children’s Hospital of Eastern Ontario. As a result of these consultations it was decided to add to graphical presentation the text label standing for the appropriate activity. These text labels (*Hx* for History, *PE* for Physical Examination, *Ix* for Tests, and *TR* for Triage recommendation) are typical short forms used by physicians in describing routine activities on patient’s chart.

Color

Use of color should be consistent and not overabundant in order to enforce end-user focus on the task to be accomplished. *MET* interface relies on few colors that are limited to icons and pictograms only. The colors enhanced with text labels on the icons are used as a visual cues to reinforce distinction between the four main triage activities.

Inputting Data

Data entry on a handheld device generally involves using a stylus and writing graffiti, or using the virtual pop-up keyboard and number pad. It is difficult to master quickly these data entry modes, so we decided to significantly diminish this input mode in the *MET* system, and replace it, whenever possible, with the alternative modes that do not require use of graffiti or alphanumeric keypads. In the case of two-valued attributes (i.e. those taking yes/no, present/absent, *etc* values) it was achieved by presenting check boxes with a toggle on/off function (see Figure 5). Check boxes are familiar constructs to all who have ever filled out a form, and therefore, they were selected over pull down lists or other similar solutions. Multi-valued attributes, such as site of pain, temperature, or duration of pain require different data entry solutions. In the *MET* system we decided to use pictograms and other graphical representations that are familiar to the physicians. For example, site of pain is determined by first tapping on an icon of an abdomen, which appears when the given attribute is selected (see Figure 6).

Figure 5. Using check boxes.

Figure 6. Selecting an attribute.

This action transfers a user to a separate dialogue screen displaying an abdominal image where he/she is able to identify specific location of pain on the abdominal photograph by tapping the appropriate area (see Figure 7). Similarly, the temperature is entered using slider that is linked to an image of a thermometer where the 'mercury rises' as the slider is being moved to record patient's fever (see Figure 8).

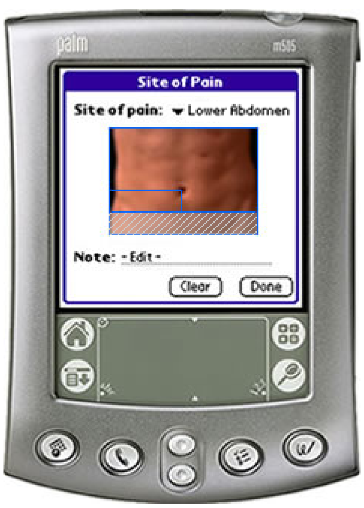

Figure 7. Screen for site of pain attribute.

Figure 8. Screen for temperature attribute.

Utilization of graphical controls (photographs, pictograms) for selected data entry items enhances cognitive association between task and *MET* function by presenting the end user with an image that is very closely associated with the clinical activity he/she is familiar with.

Writing Comments

Physicians are accustomed to writing comments on charts, so it is important that the *MET* system also has such facility. Following our earlier assumption about cumbersome use of graffiti, we decided for an alternative comments entry format. After analyzing hundreds of patients' charts, we have developed a

Published in European Journal of Operational Research (special issue after HCP'2003), in press

set of frequently used terms and keywords and implemented them as small buttons located at a bottom of the comments screen (that is accessible for almost all clinical symptoms and signs used in the system). The physician simply needs to tap on the varying buttons to create a simplified statement (see Figure 9).

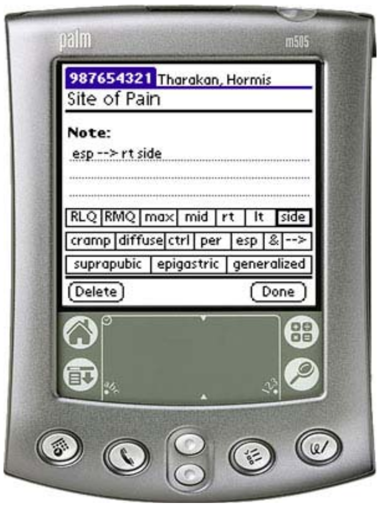

Figure 9. Writing comments.

Discussion

As with any man-machine interactions framework, feedback from the intended end-users is extremely important for practical acceptance of a system. Throughout the design stage, medical students, medical residents, ER physicians and paediatric surgeons were consulted about alternative design solutions. These consultations, combined with adhering to the principles of user-centered and domain-specific design resulted in an interaction framework that is intuitive, easy to use and supports the tasks at hand. It allows the ER physicians to focus on the interaction that take place while conducting the patient interview or physical exam and provides for a seamless transition between the tasks of gathering and entering data and triaging a patient. Thus, we have developed man-machine interaction solution for mobile device that is in line with end user cognitive expectations and minimizes cognitive burden associated with a change that accompany use of a computerized support tool for ER triage decision. Because of the initial very positive reception of the *MET* system, it will proceed into regular clinical trial in the ER in the Spring 2003. Results of such a trial may impact specific design solutions, but basic principles most likely will remain the same.

With the development of the *MET* system we have demonstrated that creative use of existing design frameworks, combined with the thorough understanding of the application domain is essential for the successful development of man-machine interactions appropriate for medical domain. We have shown that even complex applications (much more sophisticated than standard address books or to-do lists available for handheld devices) can be implemented on mobile devices if their design follows principles of simplicity enhanced with domain-specific and user-centered guidelines.

A clean and intuitively designed interactions for a clinical application have the additional advantage of contributing to structured collection of information about a patient's condition. Several studies (Glas *et al*., 2002; Guerlain *ET al*., 2001) have shown that structured data collection and the use of standardized forms to collect data about a patient, improve the diagnostic performance of ER medical personnel in evaluating patients' conditions. This aspect should not be underestimated while deciding about a format of man-machine interactions in clinical support systems.

Acknowledgement

Research described in this paper was supported by the grants from the Natural Sciences and Engineering Research Council of Canada.

The *MET* mobile component was developed using *AppForge MobileVB* and *Extended Systems Mobile Objects*.

References

Glas, A., Pijnenburg, B., Lijmer, J., Bogaard, K., de Roos, M., Keeman, J., Butzelaar, R., Bossuyt, P. (2002). "Comparison of Diagnostic Decision Rules and Structured Data Collection in Assessment of Acute Ankle Injury." *Canadian Medical Association Journal* vol. 166, no. 6 pp. 727-33.

Guerlain, S., LeBeau, K., Thompson, M., Donnelly, C., McClelland, H., Syverud, S., and Calland, J. (2001). "The Effect of a Standardized Data Collection Form on the Examination and Diagnosis of Patients with Abdominal Pain." *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting*, Minneapolis, Minnesota, pp 1284-1289.

Gulliksen, J. (1996). "Designing of Efficient Human-Computer Interfaces in Working Life by Means of a Domain Specific Approach". Graduate Thesis, Uppsala University.

Gulliksen, J., and Sandblad, B. (1995). "Domain Specific Design of User Interfaces." *International Journal of Human-Computer Interaction* vol. 7, no. 1 pp. 135-151.

Gulliksen, J., Johnson, M., Lind, M., Nygren, E., and Sandblad, B. (1993). "The Need for New Application Specific Interface Elements". In G. Salvendy and M.J. Smith. (eds.) *Human-Computer Interaction*, Proceedings of the 5th International Conference on Human-Computer Interaction, Orlando, Florida, pp. 15-20,.

Weinger, M. (2000). "User-Centered Design: A Clinician's Perspective". *Medical Device and Diagnostic Industry Magazine* no. 1 pp. 80 – 88.

Wiklund, M. (1998). "Making Medical Devices More User-Friendly". *Medical Device and Diagnostic Industry Magazine* no. 5 pp. 177-186.