A Pen-Based System to Support Pre-operative Data Collection Within an Anaesthesia Department

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This paper describes the design and implementation of a pen-based computer system for remote pre-operative data collection. The system is envisaged to be used by anaesthesia staff at different hospital scenarios where pre-operative data are generated. Pen-based technology offers important advantages in terms of portability and human-computer interaction, as direct manipulation interfaces by direct pointing, and "notebook user interfaces metaphors". Being the human factors analysis and user interface design a vital stage to achieve the appropriate user acceptability, a methodology that integrates the "usability" evaluation from the earlier development stages was used. Additionally, the selection of a pen-based computer system as a portable device to be used by health care personnel allows to evaluate the appropriateness of this new technology for remote data collection within the hospital environment. The work presented is currently being realised under the Research Project "TANIT: Telematics in Anaesthesia and Intensive Care", within the "A.I.M. - Telematics in Health CARE" European Research Program.

INTRODUCTION

The most common pre-operative activities to be carried out by anaesthetists and other related health care personnel within a hospital environment [1] are those concerned with information retrieval from patient interviews and clinical sources, decision making on pre-medication, and anaesthesia techniques and control during induction. In addition, anaesthesia staff must observe administrative and legal requirements. These activities can be carried out at different physical environments and they are identified by the specific circumstances associated to the patient. Three pre-operative scenarios are considered [2] (figure 1.):

A) Ambulant or hospitalized patient with a known diagnosis. The operation can be planned after the patient registration. Patient is interviewed by the anaesthetist and is hospitalized or sent back home with a treatment. The date planned for operation, the patient returns to the hospital (if he doesn't remain there), where he/she is prepared for operation.

B) Patient with an unknown or known diagnosis that has been hospitalized in such a condition that he/she requires an operation within 12 to 24 hours. All patient consultations and examinations are at the bed site few hours before the operation.

C) Emergency patient, who has to be operated as soon as possible. This patient will often require an immediate anaesthesiological surveillance. He is sent without delay to an emergency operation room or to a recovery room, where the anaesthetist will try to obtain as much data as possible.

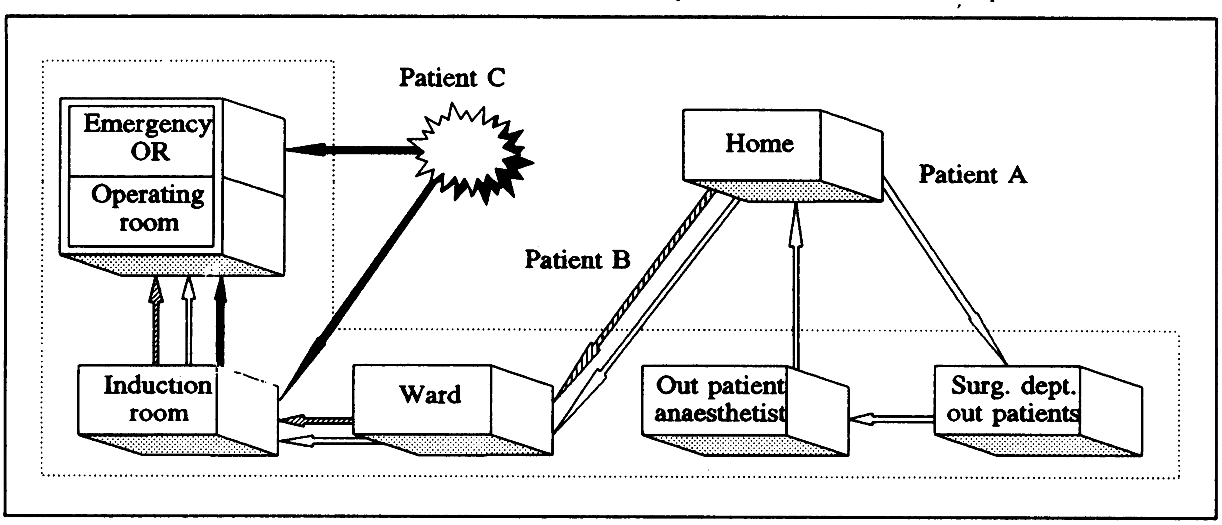

Figure 1: pre-operative scenarios.

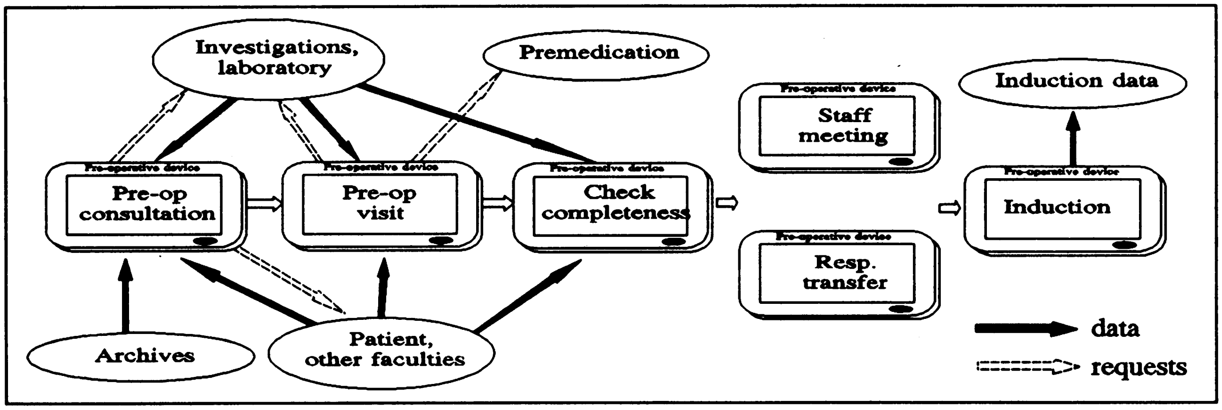

Figure 2: anaesthetist main activities.

In this three situations, remote data collection is needed to create and upgrade progressively the pre-operative data record.

In some hospitals, whenever is possible, anaesthetist prefer to "see" type A patients in consultancy few days before the planned operation date to guarantee that all required pre-operative examinations/investigations will be available in time.
For patients type B the anaesthetist visits them for a pre-operative examination the day (evening) before the operation starts.
Finally, due to the specific features of patients type C, it can be considered that their data flow and processes are embedded in the processes followed with other patients, normally with a different timing, data completeness and data capture context.

As it will be described later in this paper, the design and implementation of a portable data collection system is built on a pen-based computer. The 'notepad computing' or pen-based technology defines a new paradigm for portable computers [3]. It is a combination of the classical PC technologies with the most familiar form of recording information. With a 'notepad' computer users print, draw and mark with symbols or gestures using a "pen-like" input device and a LCD digitizer screen as a "paper". Pen-based computing market can be divided into two categories: the high end and the low end. On the low end, DOS-based systems using the 8086 or NEC V20 architecture prevail. The high end is capable to support 'Windows for Pen Computing' and 'PenPoint' operating systems.

Very few experiences have been reported on the use of pen-based technologies to data collection at hospital environments [4]. Here, the design and implementation of a pen-based system to support pre-operative data collection within an anaesthesia department, is presented.

SYSTEM DESIGN AND IMPLEMENTATION

The analysis of the general pre-operative framework described above leads to an initial set of main activities (shown in figure 2) to be carried out by anaesthetist at the pre-operative phase and to be supported by the system:

1) Pre-operative consultation. Performed few days before or included in the pre-operative visit to the bedside.
2) Pre-operative visit to the bedside.
3) Consult patient anamnesis data, estimation of patient risk in the next phases (induction, operation), consult the most recent laboratory data.
4) Prescription of pre-medication and required therapeutical interventions.
5) Control the completeness of pre-operative patient's record.
6) Transfer responsibility to other anaesthetist.
7) Staff meeting to discuss relevant cases.
8) Prepare/plan the anaesthesia.
9) Reviewing data during induction in case of no computer system and no printed pre-operative protocol in induction room.

Hierarchical task analysis

The next step after achieving the user requirements is the hierarchical analysis of tasks (HTA) [5]. Firstly we identify the main user tasks supported in some manner by the pre-operative system (described above), and secondly we analyze each task by decomposing them into sub-tasks, and recognising their hierarchical relations. This analysis is performed with a level of detail (granularity) that avoids any assumption on a functionality and dialogue design, because we use this tasks analysis method to produce functional and user requirements (HTA could be used also to measure the cognitive complexity of an already designed interface). Therefore, the decomposition stopping rule is the following: decomposition continues until the stated sub-task may be attained by carrying out interface responses (operations that directly change the state of the system); the last sub-task described will be a simple task.

With this decomposition we identify those simple tasks repeated along different main tasks; these will be basic functions of the system, which will have the same behaviour and design to assure interface consistency, a fundamental design guideline of human computer interfaces. Furthermore, if we represent graphically the complete sub-tasks hierarchy for all the anaesthetist activities, it is possible to clearly view the main user tasks (decomposition starting tasks), that are achieved by different 'simple tasks'. These independent main tasks could be supported by also independent functionalities provided by the system. To the independent functionalities will be added the functional requirements forced by legal, administrative, or Hospital Information System integration needs (which are not necessarily activities desired by the user) and all of them will use the basic functions to reach their goals.

The main user tasks were extracted from the above-mentioned description of anaesthetist activities at the pre-operative phase and the identified 'simple tasks' after main tasks decomposition are:
1) Select patient.
2) Select data by groups to be viewed on screen.
3) Hand writing information (edit the data group).
4) Generate requests (investigations, pre-medication, additional diagnostic procedures).
5) Retrieve data from other computer system.
6) Transmit data and requests to other systems.
7) Visualization of completeness.
8) Identification of users.
9) Check of data.
10) Record user signature.
11) Consult the selected cases.
12) Computer-system checking of anaesthesia equipment.

Identified basic functions must be completed also with other functions suggested by design guidelines, which take into account the user model, the environment, and general recommendations about the design of usable interfaces (on line help, undo keys, etc) [6]. Some of the guidelines which refer to dialogue design are the following [5]:
an appropriate dialogue must,
- support an efficient tasks finalization;
- be consistent as expected by the user;
- be error tolerant;
- be user controllable; the user should decide what to do next and how to solve a task, without being force to follow a path;
- be auto-descriptive, and ease of learn.

Taking into account these guidelines it should be decided the grade in which the user is guided by the system on the accomplishment of the tasks.
In our case, the pre-operative system must be flexible to make ease the system use in different scenarios (patient A, B and C). Each scenario implies variations in environment and user tasks. Consequently, we avoided to implement all the main tasks as system main functions when they are constituted only by simple tasks that are repeated a reasonable number of times; moreover, the

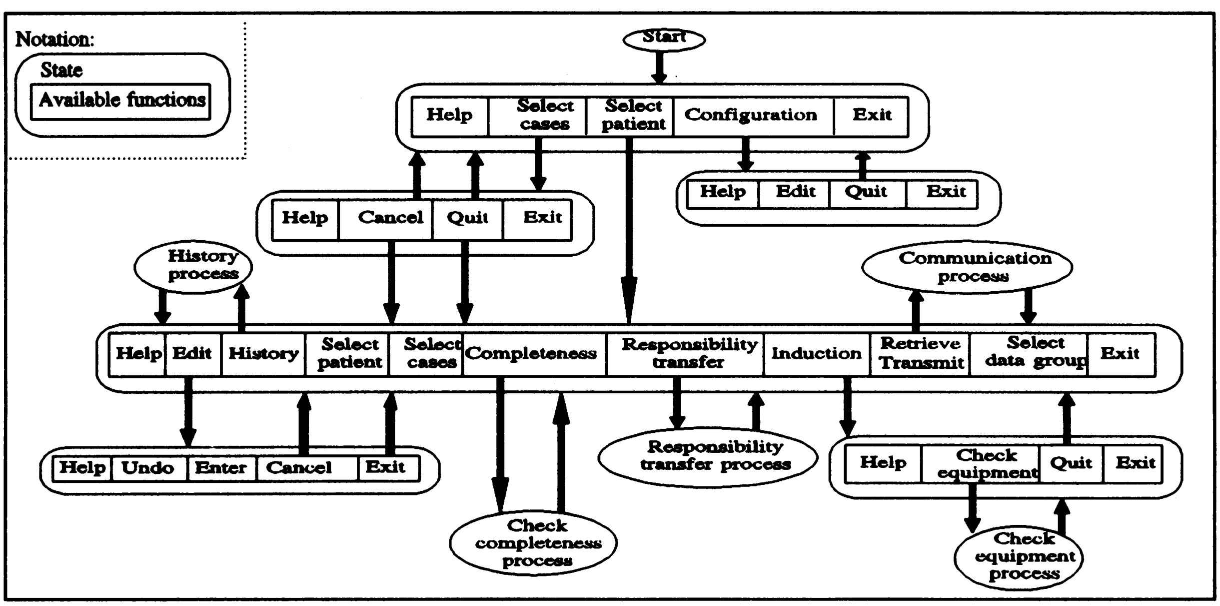

Figure 3: transition state diagram.

constituent basic functions must be implemented separately. Observing the tasks hierarchy we can also found the functions that only can be performed if another determined function was completed before.

To simplify the use of the pre-operative system, and as a consequence of another general recommendation which suggests that only should be displayed on screen the required information in each case, we design the system behaviour by selecting the available functions in each system state. In figure 3 is represented the system behaviour by a transition state diagram.

Hardware and software environment

In order to select the more appropriate hardware and software platform for a remote data collection system to support the functional specification depicted on the previous section, a technical review of several portable computers was carried out. We analyzed the so called 'laptops', 'notebooks', 'subnotebooks', 'palmtops' or 'pocket computers' and 'notepads' or 'pen-based systems', and the parameters evaluated were: portability (weight, dimensions), operating system (MS-DOS compatibility, Windows environment support), user interface (display, keyboard, pointing devices), memory, storage options, I/O interfaces (integration to Hospital Information Systems), operating times-work autonomy (battery) and price.
The system finally adopted is included in the high end of the pen-based computing market, and was a NCR Model 3130 NotePAD with the following general technical features: 20 MHz Intel386 SL microprocessor, 16 KB cache memory, 8 Mb RAM memory, LCD screen with back illumination, digitizer, 640x480 pixel VGA compatible, 16 grey levels, and 'Windows for Pen Computing' operating system.

The tool, with pen handling, used in the software development was 'Microsoft Visual Basic 3.0 Professional' for Windows applications. The database files were developed with 'Microsoft Access', which is integrable with 'Visual Basic' and supports almost all database files in the market; the database engine included in 'Visual Basic 3.0' is responsible of data management. The communication link with the hospital information system and anaesthesia department system is achieved by a serial communications line implemented with the facilities provided also by 'Visual Basic 3.0', which also allows modem communications.

Human-computer interface

It has been selected the 'Notebook metaphor', a notebook with paper sheets and tabs between them to classify and to clearly distinguish data groups. Each group is selected 'turning the page', that is to say, pushing the tabs with the pen. To exploit the direct manipulation provided by the pen, all functions are represented by push buttons with suited icons and a significant key word, which offers immediate feedback to the user.
The dialogue between the user and the system is accomplished by direct manipulation of push buttons, the tabs, the options selection controls, and by free annotations (including user signs). Specifically, the data that is not obtained from other systems by serial communications is manually introduced in the database by pen direct selections on option lists ('combo boxes' and 'option buttons'). In addition, it is included a screen simulated keyboard, handled also by pen direct manipulation, to help on manual data collection.

The general screen layout is divided in three areas: the data area, including the graphical notebook with tabs for each data group; the message area, with a text line to display system information; and the function buttons area, with eleven command buttons to initiate an immediate action (carrying out or cancelling a command) or to enter in other task.

An screen example is presented at next page (figure 4) which shows the 'responsibility transfer' task. It can be observed the system capability to digitize signs, a critical system function to cope with legal and administrative requirements that can be supported by 'pen-based systems'.

DISCUSSION

Our aim is to design a system that helps in the achievement of the pre-operative work, coping with legal requirements, usable in several environments and situations during pre-operative phases, without increasing the anaesthetist workload.
To reach these goals the greatest effort was dedicated to design the human interface following a usability approach, which has led us to select a pen-based system, that offers a pen direct manipulation, combined with a great portability.

In spite of today's handwriting recognition limitations, pen-computing is adequate for short annotation and form-filling, where data can be directly selected from options, which is exactly the intended use of the pre-operative system designed.

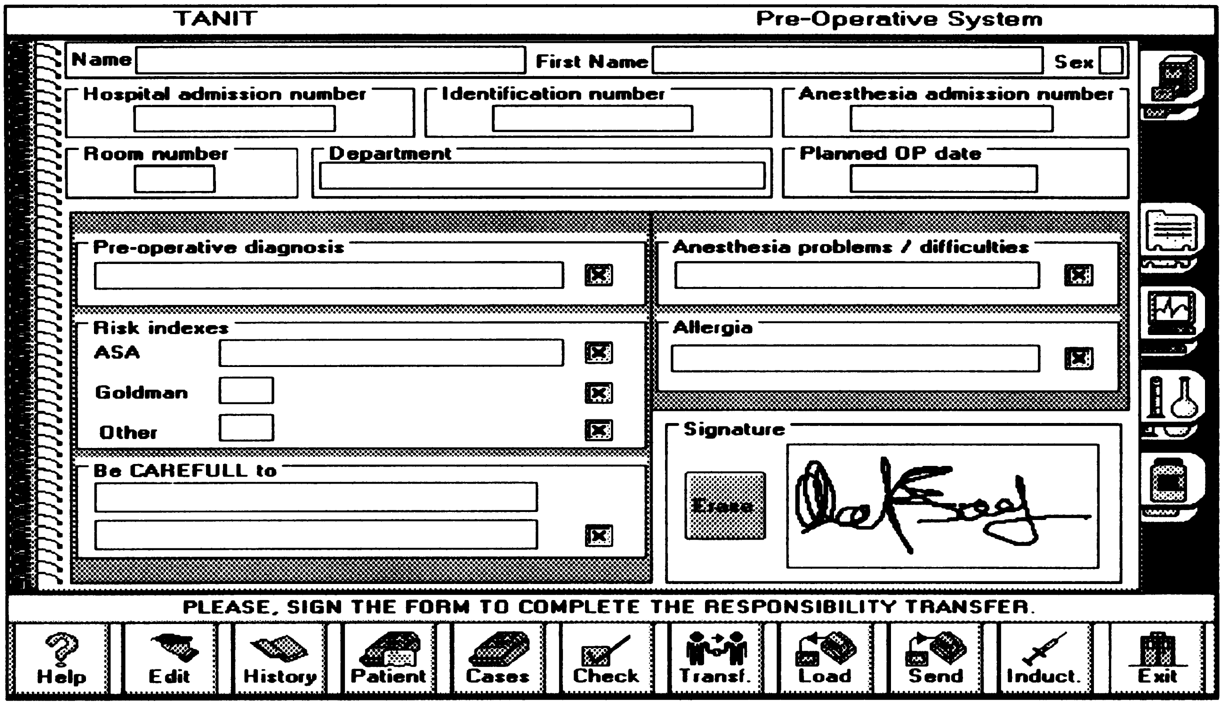

Figure 4: example of user interface screen layout.

We have proposed a methodology to evaluate the system and to detect usability defects ([5],[6]), in the framework of the project "TANIT" (see acknowledgments). Due to the importance of the evaluation in a real environment (evaluation in context) [6], the main usability data collection technique is 'input logging' (automatic recording of human-machine interaction) [7]. This method, without intrusion, concurrent and objective, is complemented with user questionnaires and interviews to obtain subjective data, which allows a crossed analysis with the data obtained in the input logging. From the very beginning of the system development it has been implemented a set of data collection procedures to support the input logging method [7].

The "TANIT" Project is still under development and the evaluation of the pre-operative system in a real environment has not been performed yet. Nevertheless, initial outcomes from user interface evaluations with real users, make us to foresee a good system acceptance, taking into account the importance of this component for the system usability.
Finally, this pen-based technology application opens new possibilities for an envisaged use of mobile computing within hospital environments.

Acknowledgments

The authors would like to thank Philippe Grevisse and Michel Demeester from Staff Company (Belgium) for their help on the definition of the application environment.
This works was supported in part by the EEC Programme A.I.M. - Telematics in Health Care under the Project "TANIT-Telematics in Anaesthesia and Intensive Care".

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