

# Mobile Devices in Emergency Medical Services: User Evaluation of a PDA-based Interface for Ambulance Run Reporting

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**Abstract.** The design of easy-to-use mobile systems for collecting and handling emergency medical care data in the field can significantly improve the effectiveness of rescue operations. In particular, this paper focuses on the design and evaluation of a mobile application that replaces ambulance run paper sheets. First, we discuss the limitations of traditional ambulance run paper sheets. Then, we present the PDA-based system we have developed. Finally, we discuss in detail the usability study we have carried out with first responders.

## 1 Introduction

In emergency medicine, prompt, accurate recording and communication of patient data can make the difference between life and death [1]. Traditional information collection in the field and communication to the next level of care is often inaccurate. For example, during interviews conducted by [1], medics reported that typically 40 percent of the fields on an ambulance run sheet for a trauma incident are either left blank or filled in erroneously.

The design of easy-to-use systems for collecting and handling emergency medical care data can significantly improve the effectiveness of rescue operations by satisfying first responders' needs such as: (i) enhancing operations timeliness by allowing to efficiently record and communicate data between on-site teams and headquarters; (ii) being able to efficiently perform on-site patient classification using severity color coding (*triage*), by rapidly applying a set of criteria (*triage protocol*); (iii) being able to get information from medical databases that could help in choosing a proper course of action in the field; (iv) getting real-time information about nearby hospitals and/or medical care facilities, checking their availability and therapeutic capabilities, and communicating data to them. Moreover, digital reports can be stored in databases and

enhance knowledge management capabilities of emergency services (e.g., automatic assessment of quality of service).

This paper focuses on the design and evaluation of a mobile application that replaces the traditional ambulance run paper sheets. While other researchers pursued this goal by using full PCs installed on ambulances [2] or using belt computers, speech recognition technologies and tablet handhelds [1], we focus on smaller, lightweight devices, and aim at a data entry style that has to be unaffected by environmental noise and as similar as possible to traditional paper sheet filling to be familiar and quickly adoptable by first responders.

## 2 The proposed system

In this section, we illustrate some of the main features of the system that is being jointly developed by the Human-Computer Interaction Lab of the University of Udine and the Emergency Medical Service of the Hospital of Udine, Italy. Besides replacing current paper sheets, the system aims at introducing new functionalities that are not supported by paper sheets and is developed following a user-centered methodology.

### 2.1 The traditional ambulance run sheet and its limitations

Medical teams on ambulance trucks and helicopters typically record data about the rescue operation on the so-called *ambulance run sheet*, i.e. a paper sheet where they write down information about the incident, patient conditions, actions taken, and rescue team members.

The contents of a typical ambulance run sheet are split up in sections. The specific ambulance run sheet we considered is organized into 9 sections: *Evaluation*, *Treatment*, *Pharmacologic Therapy*, *Anamnestic Data*, *Home Therapy*, *Diagnosis*, *Outcome-Transport-Alerts*, *Mission Data*. These sections are usually filled in the reported sequence, but the first responder is free to follow a different order.

Using paper for information recording has clear limitations, both in data entry and information representation. When a user miswrites something, corrections result in reports that are hard to read and revise. Moreover, a paper sheet is a passive information container that is not able neither to warn the user of inconsistencies in the data nor to highlight critical situations by analyzing the entered values.

During the initial interviews with target users, it clearly came out that the layout of sections on the ambulance run sheet was designed to get the most out of the space available on a A4-sized sheet, and the arrangement of fields does not take into account neither the logical order followed by medics in filling out the report nor the classic conventions for maximizing readability in forms.

### 2.2 The mobile prototype

The proposed application aims at overcoming the above summarized limitations of the

ambulance run sheet as well as augmenting it with functionalities that were previously unavailable. It has been developed in C#, represents data in XML format, and runs on a Pocket PC platform. Pocket PCs were preferred to Tablet PCs after initial users' interviews strongly pointed out the need for a lightweight device that can be carried in a pocket of the protective suit. *Ruggedized* versions of PDAs are particularly interesting for the considered application, because they can be washed after manipulating them with dirty protective gloves.

Due to the limited size of Pocket PC displays, the original ambulance run sheet cannot be fully displayed in a single screen. We thus organized the original contents in logical parts (*sections* and *subsections*). The general structure of the user interface is shown in Figure 1 and is divided in three main parts.

The *Navigation Bar* allows one to navigate sequentially among sections and subsections, informs the user about which part of the ambulance run report is being edited, and provides further information on where the user is in the navigation structure by indicating which parts of the report precede and follow the current one. The name of the currently displayed report section (in upper case) and subsection (in lower case) is shown in the lower center of the navigation bar. Arrow buttons on the left and right of the bar can be used to navigate backward and forward as if the user were browsing the pages of a book. The labels on the arrows indicate which section and subsection the user can reach by tapping on the buttons. When there is no previous or next subsection, the corresponding arrow button is not shown.

The central part of the screen shows the contents of the *Current Subsection*. The user can visually inspect the current values of all the fields and change them.

The *Application Menu* at the bottom of the screen allows one to carry out typical file operations such as load and save through a *File* menu, and to rapidly jump to any desired section through a *Sections* menu.

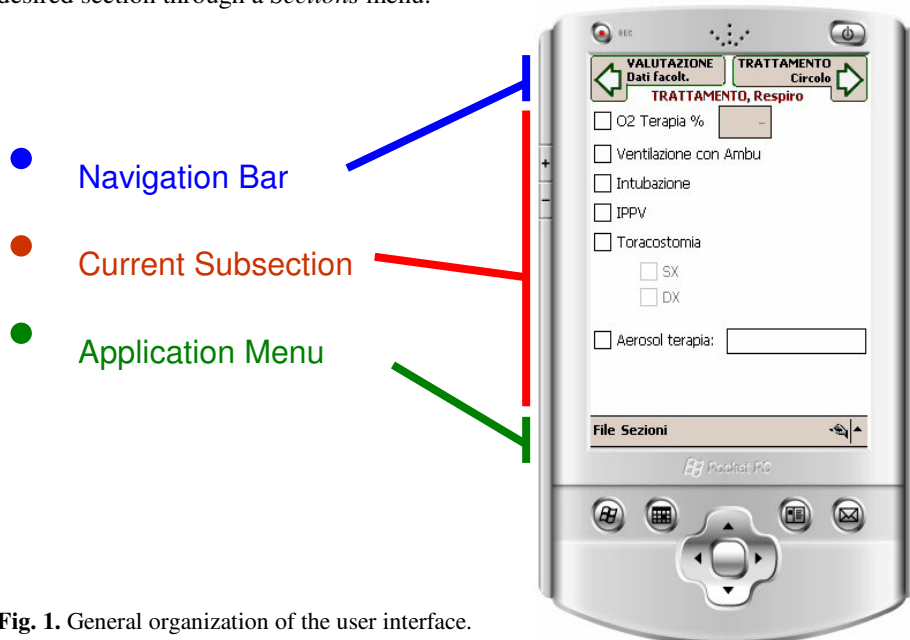


Fig. 1. General organization of the user interface.

Adrenalina	ml	
Atropina	ml	
Amiodarone	ml	
Dopamina	mg	

(a)

Risposta motoria	Ubbidisce al comando	6	6	6
	Localizza il dolore	5	5	5
	Retrae al dolore	4	4	4
	Flette al dolore	3	3	3
	Estende al dolore	2	2	2
	Nessuna	1	1	1

(b)

DATA	Ambulanza	IP	Medico	Autista
------	-----------	----	--------	---------

(c)

<input type="checkbox"/> ANTIARITMICI
<input type="checkbox"/> ANTICOAGULANTI
<input type="checkbox"/> ANTIDIABETICI
<input type="checkbox"/> IPOTENSIVI
<input type="checkbox"/> NITRODERIVATI
<input type="checkbox"/> SEDATIVI
<input type="checkbox"/> ANTIDEPRESSIVI
<input type="checkbox"/> ALTRO

(d)

REAGENTI
<input type="checkbox"/> S/N <input type="checkbox"/>

(e)

**SCHEMA LESIONI RICONTRATE**

(f)

<input type="checkbox"/> inizio manovre CPR ora _____
---

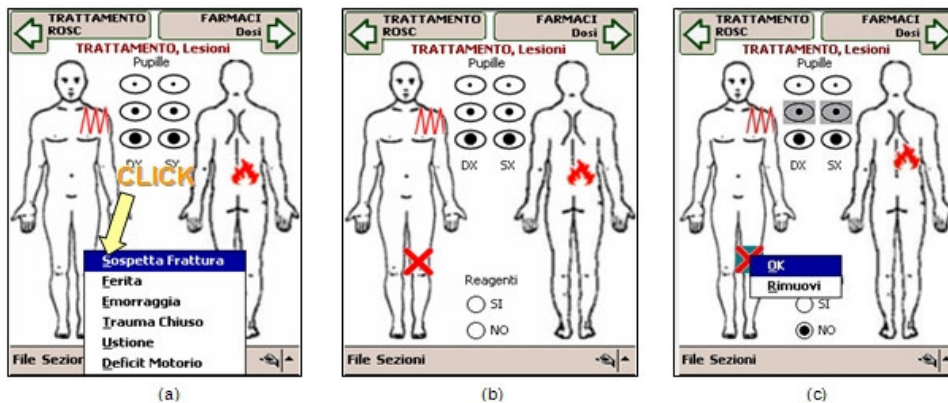
(g)

**Fig. 2.** Examples of fields in a traditional ambulance run sheet: (a) free numeric field, (b) pre-printed numeric field, (c) textual field, (d) multiple-choice field, (e) mutually-exclusive choice field, (f) graphic field, (g) mixed-type field.

The different types of input fields found on a ambulance run sheet (see examples in Figure 2) can be classified in six categories: (i) *numeric fields*, that can be divided in two subcategories: *free numeric fields* (white fields where the user is supposed to write a number) and *pre-printed numeric fields* (fields with pre-printed values that the user has to mark); (ii) *textual fields*: white space the user can fill with text (e.g., patient's name, ambulance ID, brief description of the rescue operation,...); (iii) *multiple-choice fields*: groups of checkboxes where the user can check more than one box; (iv) *mutually-exclusive choice fields*: groups of checkboxes where the user must check only one box, (v) *graphical fields*: areas on which the user can draw symbols (e.g., representing different types of injuries on a body picture to describe how and where the patient is injured); (vi) *mixed-type fields*: combinations of previously described fields (e.g., a textual field that should be filled only when a corresponding checkbox has been ticked).

For each kind of field, we developed an electronic counterpart that aims at: (i) preventing possible errors made by the user (e.g., values that are out of physically possible ranges), (ii) taking into account, where possible, the typical usage of the original ambulance run sheet, to make data entry easier and more familiar for the target users; (iii) allowing for quick editing of information, (iv) preventing erroneous or arbitrary use of the fields (that was instead possible with the paper sheet),

(iv) improving the way data is visualized on the mobile device [3], e.g., we introduced automatic color coding of the fields based on the entered values to give a quick idea of how close/far the values are from normality and also provide further feedback to highlight possible input errors. Figure 3 shows an example of the graphical interface for visually describing patient's injuries: only two taps on the screen are needed to place the proper injury symbol in the right position on the patient's body schematic. For filling textual fields, we explored a handwriting recognition approach as well as a on-screen virtual keyboard with automatic word completion. Speech recognition was not considered because the initial interviews highlighted that environmental noise in ambulance trucks and helicopters often seriously affected even human recognition capabilities when communicating with headquarters.



**Fig. 3.** To visually enter injuries, the user first taps on the injury location, then a pop-up menu lists the available types of injury and the user taps on the desired one (a), and the icon of the chosen type of injury is drawn by the system in the chosen location (b). Tapping on an injury icon allows instead to remove it or drag it to a more precise position (c).

### 3 User evaluation

The usability testing of the completed prototype took place with 6 first responders (4 male, 2 female) of the emergency service involved in this project. Their age ranged from 23 to 50, averaging at 37.5. Since we were particularly interested in the reactions of users who are not familiar with the employed technology, none of the recruited first responders had ever used a PDA before. All users had instead some familiarity (very low for two of them) with desktop PCs. The prototype was tested in the real places where traditional ambulance run sheets are usually filled by first responders, i.e. in the ambulances (see Figure 4) as well as in the emergency services rooms. More specifically, half of the users tested the system in an ambulance, half in a emergency service room. In the following, we describe in detail the task, the testing procedure and the obtained results.

### 3.1 Task and procedure

Before the test started, users were briefly taught the basic concepts needed to operate the system. More specifically, they were briefly instructed about: (i) the touch screen and stylus, (ii) the organization of the user interface in three main parts, (iii) a few tips about how to enter text using handwriting recognition software, e.g. drawing clear capital letters inside the reference grid on the screen, (iv) how to use the automatic word completion feature of the on-screen virtual keyboard. Since we were interested also in evaluating how quickly the details of the interface could be understood, no other information was given, but users were free to ask any question in case of difficulties so that we could pinpoint aspects that were possibly difficult to understand.

The task users had to carry out concerned a scenario describing a real rescue operation and was specifically written by an emergency physician to test every part of the system. Users were given an A4 sheet with the textual description of the operation, and a photograph (part of which is shown in Figure 5) shot on a real rescue mission, illustrating the scene of the accident (an hiker's fall from a mountain trail), including the patient and the equipment employed by first responders. The textual description included all the necessary clinical data needed to fill an ambulance run report. Users were asked to read the description and then fill the report using the PDA.



**Fig. 4** One of the first responders using our application inside an ambulance.

A 624Mhz PocketPC with a 3.5" display and QVGA (320x240) resolution was employed for the test. Textual data entry was handled through a commercial software (Phatware Calligrapher [4]), in the handwriting recognition mode (recognition of entire written words) as well as virtual keyboard mode (with automatic word completion), both configured to recognize Italian words. To test both textual data

entry options, the textual field describing the accident was filled by users through handwriting recognition, while the textual field for clinical notes was filled by users through the virtual keyboard. The description of the accident for this scenario was about 7 words long, while the clinical notes were about 26 words long.

After users completed the task, we employed a questionnaire to collect their subjective opinions concerning the usability of the system. The questionnaire included 5 open-ended questions and 21 statements that had to be rated by users on a numeric scale ranging from 0 to 9. The 5 questions concerned which features the user liked and disliked, possible advantages and drawbacks of the system with respect to the paper run report, and suggestions on how to improve the application. The 21 statements were taken or adapted from the standard QUIS (Questionnaire for User Interaction Satisfaction) [5], and divided in five groups, each one dealing with a different aspect of the user experience: Overall reactions to the software, Screen, System information, Learning and System capabilities. The statements, as well as means and variances for the collected answers are reported in Figure 6. After completing the questionnaire, we freely discussed with users to possibly get more feedback from them about the system.



Fig. 5. Part of the photograph illustrating the scene of the accident.

### 3.1 Evaluation results

In general, the results of the evaluation were much more positive than we expected. Although they had never used a PDA before, all 6 first responders quickly learned how to effectively operate the system and expressed willingness to employ such technology in their daily practice. All but one of the 21 statements in the questionnaire received very good ratings, and most of them with a small variance.

	Mean	Var.
<b>Overall reactions to the system</b>		
The system is (0=Difficult, 9=Easy)	8.5	0.3
The system is (0=Uncomfortable, 9=Comfortable)	7.3	1.5
The system is (0=Rigid, 9=Flexible)	7.2	2.2
The system is (0=Dull, 9=Stimulating)	8.0	0.8
<b>Screen</b>		
Characters on the PDA screen are (0=Hard to read, 9=Easy to read)	7.5	1.1
Organization of information on screen is (0=Confusing, 9=Clear)	8.3	0.3
Sequence of screens is (0=Confusing, 9=Clear)	8.5	0.3
Use of color for data representation is (0=Useless, 9=Useful)	8.7	0.3
<b>System information</b>		
[In case the system showed you error messages] Error messages are (0=Unhelpful, 9=Helpful)	8.0	2.0
<b>Learning</b>		
Learning to operate the system is (0=Difficult, 9=Easy)	8.2	0.2
Exploring new features by trial and error is (0=Difficult, 9=Easy)	8.7	0.3
Remembering names and use of commands is (0=Difficult, 9=Easy)	8.2	0.6
Tasks can be performed in a straightforward manner (0=Never, 9=Always)	7.7	0.3
<b>System capabilities</b>		
System speed is (0=Too slow, 9=Fast Enough)	8.3	0.7
System reliability is (0=Low, 9=High)	8.0	0.8
Entering numeric values is (0=Hard, 9=Easy)	8.7	0.3
Writing text using handwriting recognition is (0=Hard, 9=Easy)	3.8	6.6
Writing text using the on-screen virtual keyboard is (0=Hard, 9=Easy)	7.2	1.8
Using the graphical injury diagram is (0=Hard, 9=Easy)	8.2	0.6
Entering other kinds of data is (0=Hard, 9=Easy)	8.2	0.6
[In case you have corrected errors] Correcting errors is (0=Hard, 9=Easy)	8.0	0.5

**Fig. 6.** Results for the statements in user questionnaire.

Users had no problems in understanding and navigating the sections/subsections structure. Some of them even stressed how they felt such an organization of content was useful because it suggested a well defined way of filling up the report: they felt



that displaying data fields in a logically ordered sequence of screens made them take into account every part of the report, reducing the possibility of leaving relevant fields blank because they have not been viewed or considered. Entering and editing the data fields was also considered to be very simple. Users were able to rapidly understand how to handle the different types of data fields and the corresponding input technique. They were also positively impressed by the new features of the PDA-based report, such as criticality color coding or graphical interaction with standard symbols automatically and clearly drawn by the software in the injury subsection.

The rating of the statement about handwriting recognition indicates a usability problem. Results obtained by the considered users with handwriting recognition were not satisfactory: most of their written words were not correctly recognized, and they had trouble following the writing tips suggested at the beginning of the test, because it felt unnatural to them. The high variance of this rating is due to the fact that although all users were dissatisfied with the results, two of them did not rate negatively the feature because they felt the input method could perform better with practice. Two users reported that the available screen space was insufficient for them to write a long word entirely. Moreover, three users expressed concern about the effectiveness of this method when used on a moving ambulance.

The virtual keyboard led to better results and the word completion feature was able to suggest also some medical terms. However, letter-by-letter typing was time consuming for all users. This was seen as an advantage by one user, who reported that using the keyboard forced him to be more concise in writing textual descriptions on the report. An interesting comment that came from another user was that she would be writing faster using a T9-like input system tailored to medical terms and abbreviations. She pointed out the fact that she and her colleagues are very familiar with typing SMS messages on cell phones. Four users reported that keyboard keys were too small, and hard to read and use. We further elaborate on textual data entry in the next section.

Some users remarked that sending the data through a PDA could improve communication between them and their headquarter in terms of speed and reliability, since today they communicate much information by voice through mobile phones or radios from noisy environments. Electronic reports were also perceived by first responders as a more secure way of recording data, since paper sheets can be torn, soiled or lost.

## **4 Conclusions and future work**

The informal evaluation showed that first responders who are completely unfamiliar with PDAs can quickly learn how to use the proposed ambulance run reporting application, without the need for a particular training.

We are currently working at the handwriting recognition issue that came out during the evaluation, and we plan to consider different options to offer an easy-to-use and efficient text input method to the target users. One possibility would be to implement a T9-like input system relying on a medical dictionary. Users could be presented with an

on-screen phone-like keyboard, possibly with larger keys and more convenient controls for symbols and punctuation. Considering the widespread usage of cell phones, this technique could be a good choice also for people who are not familiar with the QWERTY layout. It would also eliminate the problem of having a full keyboard squeezed into the PocketPC screen, that forces the size of the keys to be very small. Another option could be to use a format such as UNIPEN [6] or InkML [7] to represent digital ink information. Such data can then be processed by a recognition software (most likely running on a server rather than the PDA) to translate handwriting into text. For example, LipiTk [8,9] is an open source generic toolkit that supports the UNIPEN format natively, can support different recognition algorithms and is meant for the development of online handwriting recognition engines. We are also considering the possibility of limiting the need for handwriting as much as possible through a mechanism for assembling the text by selecting sentences or words from pre-compiled lists specific to the ambulance run domain.

Another interesting development of the system could concern functionalities for receiving data directly from monitoring devices, such as the ECG monitor, that are available onboard ambulances.

Moreover, we have also started working at an adaptive version of the user interface with the aim of (i) automatically proposing the next most appropriate fields to fill based on the information previously entered in the report, (ii) guiding first responders to comply with the correct medical protocols in accordance with the clinical scenario they are dealing with, by introducing into the system an advisory capability based on medical knowledge.

## References

1. Holzman, T.G.: Computer-Human Interface Solutions for Emergency Medical Care, ACM Interactions, Vol. 6, No. 3 (1999), 13-24
2. Anantharaman, V., Han, L.S.: Hospital and emergency ambulance link: using IT to enhance emergency pre-hospital care, International Journal of Medical Informatics 61 (2001) 147-161
3. Chittaro, L.: Visualizing Information on Mobile Devices, IEEE Computer, Vol. 39, No. 3 (2006), 40-45
4. Phatware, <http://www.phatware.com>
5. Chin, J.P., Diehl, V.A., Norman, K.L.: Development of an instrument measuring user satisfaction of the human-computer interface, In: Proceedings of the CHI '88 Conference on Human Factors in Computing Systems, ACM Press, New York (1988) 213-218
6. Guyon, I., Schomaker, L., Plamondon, R., Liberman, M., Janet, S.: UNIPEN project of on-line data exchange and recognizer benchmarks, In: Proceedings of the 12th International Conference on Pattern Recognition (ICPR '94), IAPR-IEEE, 29-33 (1994)
7. InkXML, <http://www.w3.org/TR/InkML>
8. Madhvanath S., Vijayaseenan D., Kadiresan T. M.: LipiTk - A Generic Toolkit for Online Handwriting Recognition, In: Tenth International Workshop on Frontiers in Handwriting Recognition, IRISA, France (2006)
9. LipiTk open source software, <http://lipitk.sourceforge.net/>