Towards adaptive user-interfaces: Developing mobile user-interfaces for the health care domain

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Abstract: This paper focuses on the development of mobile user-interfaces for disaster scenarios. We propose different concepts how unpredictable and unstable situations can be controlled with the use of adaptive mobile user interfaces. These concepts contribute to the development of more intuitive and adaptive mobile user-interfaces in disaster scenarios. Furthermore we identify possibilities for the improvement of existing mobile user-interfaces in more stable environments with less critical requirements. We point out how presentation of as much information as required and as little information as possible can be achieved by taking the current situation of the users into account. A specific view on the database is presented to each user individually depending on his current duties and responsibilities. In the health care domain different types of information are required by potential users, such as static, patient related and environmental information. The intention of this paper is to stress the importance of adequate mobile user-interfaces in health care applications and to propose how this demand can be met at the best.

1 Introduction

Mobile user-interfaces which fulfill the requirements of health care applications differ significantly from standard mobile user-interfaces. The medical personnel have to have its focus primarily on the patients and their treatment according to their individual needs. Documentation of patient condition and performed care usually has to take a secondary role in day to day business. For example in hospitals this is done by nurses who on the one hand assist the physician and on the other hand document all medical treatments. The majority of mobile computer-based systems mainly focuses on the documentation task. In this paper we present our approach to support the medical treatment as well. Basically three different types of information are necessary during the patient's treatment: general (static) knowledge about special treatment techniques, patient related information (including the patient record) and peripheral information.

The need for static information depends on the experience of the physician and on the incidence rate of a certain disease or injury. The more experienced the physician is and the more often a certain disease or injury occurs, the less the static information is required

during the patient treatment. The patient related information required during the treatment is independent from the physician's experience. The time needed for retracing the patient's history, however, depends indirectly on the doctor patient relationship. The longer the doctor knows the patient, the less time is needed for recalling. In the worst case, the doctor has never seen the patient before and has to deduce all relevant information from the entire patient record. Peripheral information is especially important if the environment is not fully known by the physician, is uncontrolled or constantly changing. Peripheral information includes the state of all other patients, actions of all other physicians and information on the overall situation. The more unstable and unpredictable these parameters are, the more often the physician has to be supplied with new peripheral information. Consequently scenarios in which well experienced doctors perform common therapies, are familiar with the patient history and work in a stable periphery have low requirements on mobile user-interfaces. Furthermore it is more difficult to assess the quality and adequacy of mobile user-interfaces due to the fact that all occurring tasks can already be solved without mobile computers equally well. In unusual scenarios, however, which occur with lower frequency, where the physicians have no previous knowledge about the patient history and in which the environment is highly unpredictable and unstable the introduction of mobile user-interfaces poses a significant challenge.

2 Motivation

This paper focuses on the development of mobile user-interfaces for disaster scenarios. Due to the fact that disasters occur in low frequency the paramedics and physicians are never completely familiar with disaster specific procedures. All involved medical relief units mainly gain their knowledge from disaster control exercises. Furthermore in this scenario the paramedics and physicians medicate patients with an a-priori unknown patient history. Because of the special environmental conditions relief units are assigned to more than one patient and this patient may be medicated by more than a single relief unit. Thus in this scenario the fast retrieval of all relevant patient related information is of crucial importance. Regarding the peripheral information this scenario makes great demands on the mobile user-interface. As opposed to stable environments, such as hospitals, in this scenario even the information on the overall situation is unpredictable and likely to change frequently. All relief units depend on frequent updates of all relevant peripheral information, such as the quantity of all involved patients, the location and condition of all patients and the activities of other relief units.

Therefore it is of crucial importance how information is presented to the relief workers in this scenario. They will only have the ability to work with mobile devices in disaster scenarios if the mobile device can completely be controlled by the them and follows existing processes and not vice versa. In this paper we propose different concepts how unpredictable and unstable situations can be controlled with the use of adaptive mobile user interfaces. These concepts on the one hand contribute to the development of more intuitive and adaptive mobile user-interfaces in disaster scenarios and on the other hand also aim to improve existing mobile user-interfaces in more stable environments with less

critical requirements. The intention of this paper is to stress the importance of adequate mobile user-interfaces in health care applications and to propose how this demand can be met at the best.

3 Related work

In recent times many improvements in the field of mobile computing have been achieved, which solve many former technical limitations [FZ94, IB94] regarding communication, portability and mobility. Chen et al. [CK00] give a survey of various context-aware mobile solutions. Concepts for mobile user-interfaces which meet the required adaptivity have been proposed by various researchers as well. The solution presented by Baus et al. [BKW02] show how mobile user-interfaces can react on the user's changing situation on the example of navigation. Billsus et al. [BBE+02] presented adaptive mobile user-interfaces for web access, considering the fact that screens are smaller, input capabilites are limited and mobile connections are slower. Schmidt et. al. [SBG99a, SBG99b] presented an approach how context-awareness can be extended in a way that it is no longer limited to the location of the mobile device.

Several publications deal with the introduction of mobile user-interfaces into the hospital environment. Favela et al. [FRPG04] propose how public, stationary displays and mobile, personal displays can be combined is hospitals to enable information sharing depending on the doctor's or nurse's location. The presentation of patient related information, general medical knowledge and hospital related information on mobile devices and a system evaluation in the hospital environment has been published by Ammenwerth et al. [ABBH00]. Ancona et al. [ADM+00] give an overview on different concepts for the information presentation in hospitals, particularly they present different possibilities for interaction with mobile hand helds.

Further hospital information systems have been proposed by Eneida et al. [MCS+04], Bardram [Bar04] and Munoz et al. [MRF+03]. Whereas for these comparatively stable hospital environments many different systems exist, on little investigation has been conducted for highly unstable disaster environments. Fischer et al. [FFB00] present an architecture for disaster management and concepts for the efficient combination of useful technologies such as GSM communication and GPS localisation. The publication by Grasso [Gra06] also basically deals with the question how reliable communication in medical disasters can be established. Killeen et al. [KCB+06], however, propose a mobile system which supports the relief worker during triage, patient assessment and documentation. Although their approach and the proposed solution is promising, it is arguable how far the proposed user-interface is adequate for the use in chaotic disaster environments.

We have recently published our first concepts for the documentation of basic medical treatments with the use of mobile user-interfaces [NK07]. The developed prototypes have been compared to current paper-based approaches in a disaster control exercise.

4 Information presentation

Due to the fact that our proposed solution is capable of storing patient and environment related information, the next challenge is to present the information in a concise way. In order to assist the relief workers to focus on the essential the presentation of too extensive and redundant information has to be avoided as well as the presentation of too sparse information. The goal of presenting as much information as required and as little information as possible can only be achieved by taking the current situation of the relief workers into account. Depending of the current duties and responsibilities of the relief worker (e.g. triage, patient treatment, documentation, transport, management or coordination) a specific view on the database is required. As already mentioned above the required information can generally be classified in three categories:

- static knowledge (algorithms, treatment techniques, coordination procedures)
- patient related knowledge (patient history, particulars, injury, treatment)
- peripheral information (number, states and positions of patients and relief workers, environmental information)

Whereas static knowledge can easily be stored on the mobile devices, the second and third type of information usually requires a wireless connection between the mobile devices. As we focus on adaptive user-interfaces and not on the development of robust wireless networks, we assume that suitable communication technologies exist and typically use a simple WLAN communication for our evaluations.

Patient related information and peripheral information depend on each other. In a sense peripheral information contains an abstraction of patient related knowledge, which leads to number, states and positions of all involved patients. In order to gain complete peripheral information additional knowledge about relief workers and the disaster environment is required. First of all we want to present concepts for an efficient presentation of static knowledge on mobile devices.

5 Presentation of static knowledge

Relief workers and doctors who are experienced in day-to-day emergency service have acquired a wide emergency related knowledge. Due to this continuous experience providing them general emergency related information is of lower importance than providing them disaster specific knowledge. Disasters occur unfrequently and therefore the disaster related knowledge is mainly achieved in disaster control exercises. Our concepts focus on the presentation of disaster specific knowledge. Knowledge which has recently been changed is most suitable for the determination of the capabilities of different information presentation concepts. We explain the concept on the example of the mSTaRT[1]-algorithm

[1] **m**odified **S**imple **T**riage and **R**apid **T**reatment

which has recently been introduced by Kanz et al. [KHK+06]. The practical realization of the abstract algorithm has already been evaluated by Gutsch et al. in a disaster control exercise [GHZ+06].

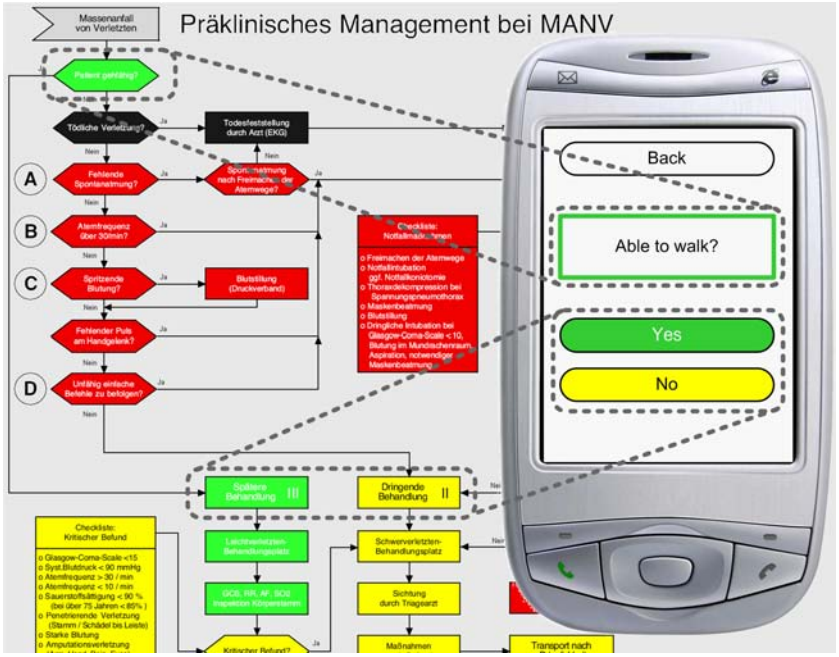

Figure 1: Straightforward transfer of the paper-based algorithm to mobile user-interfaces

A straightforward adaption of the paper-based algorithm to mobile user-interfaces is shown in Figure 1. In every step through the algorithm the user-interface gives the possibility to move in three different directions. The user can either answer in the affirmative or in the negative, additionally he can take back his last decision. These interactions correspond directly with the possibilities given by the paper-based version of the algorithm. Whereas the forward movements through the algorithm are given explicitly the backward movements are only given implicitly. It has to be stressed that this user-interface does not simply support the paramedic in the documentation task, but in fact the mobile user-interface contains the complete information on the mSTaRT-algorithm. Instead of presenting all available, complex information which is contained in the algorithm only the currently relevant information is presented to the user. On the one hand information on the current step and on all possible decisions is presented to the user, on the other hand he retrieves information on the further triage process by the coloration of the decision possibilities. As shown in Figure 1 the color indicates the least severe category, which the patient will get. In the presented step the paramedics have to check the patient's ability to walk, if the patient is able to walk he is a T3-patient which is indicated by the color green, if he is not able to walk he is at least a T2-patient which is indicated by the color yellow. Further information on

the different triage categories and the general triage process can be found in our previous publications [NK07, NDE+07].

This one dimensional approach is quite basic, nevertheless all currently relevant information is presented to the user. Due to the fact that paramedics are already familiar with the paper-based version of the algorithm, it has to be considered whether the two dimensional orientation of the algorithm steps is of importance when using mobile user-interfaces. More precisely, the question is, whether the paramedic needs the additional information that he currently is moving downwards or rightwards through the algorithm. The two dimensional context of the algorithm is getting lost in this approach. The screen size of mobile devices is strongly limited, therefore it is not possible to show the complete algorithm on the mobile user-interface at once.

Figure 2: Information presentation in 2D. (a) Checking the patient's ability to walk on the 2D user-interface (b) Visualization of current steps and triage history

A two dimensional transfer of the paper-based algorithm to mobile user-interfaces which preserves the spatial relationship of different algorithm steps is shown in Figure 2. All triage steps from the paper-based algorithm have been transferred to the mobile user-interface, the spatial relationship was preserved, and additionally the current algorithm position is highlighted and the triage path is traced. As shown in Fig. 2a all algorithm steps but the current one are shown as solid boxes in the step specific color. The tracing of the triage path is shown in Figure 2b, the previous steps are brightened up, and the paths

in-between are colored similar to the paths in Figure 1. In order to enable the paramedics to simultaneously acquire information on the complete algorithm and to triage the current patient this concept includes two different metaphors. The information acquisition is performed by directly scrolling through the algorithm by using the *stick-to-finger* metaphor. The triage of the current patient is performed by either clicking on the adjacent nodes or on the incident edges. The information acquisition does not change the patient state, the only goal is to give the paramedic the possibility to retrieve required static knowledge. The major difference to the straightforward one dimensional solution is the distinction between the presentation of static knowledge and the documentation on the basis of this knowledge.

Figure 3: Extension of the first approach. The one dimensional algorithm is combined with information about patient history.

The two dimensional user-interface presents more information to the user at once than the first one and the proposed interaction metaphors are more complex. Due to the fact that the mobile user-interface must not occupy the users complete attention during the triage process, the user-interface may only present the most important information to the user. In previous disaster control exercises paramedics stated, that the spatial arrangement of the different triage steps is less important than the patient history. Furthermore potential future decisions in their opinion are of lower importance than previous decisions. Therefore the next concept which is shown in Figure 3 combines the simple interaction concept of the first user-interface and the visualization of the patient history which was used in the second user-interface. Furthermore during the design process it became apparent that the landscape format is more appropriate for the presentation of this information than the portrait format. In the left part of the screen the one dimensional algorithm is shown and the interaction is similar to the first concept, with the exception of the backward step. The triage history is shown in the right part of the screen, by clicking on one of the past steps the user can return to this step. Therefore as opposed to the first concept, in which the user

can go back only one step at once, in this concept the user can go n steps backwards at once. This user-interface enables the user to determine the current position in the algorithm as well as the patient context quickly. The combination of detail information on the left and overview information on the right side ensures that the user is not getting confused by switching between the patient triage and the user-interface handling.

These three different concepts for transferring static knowledge on mobile devices illustrate the challenges in the design of adequate user-interfaces. First of all it has to be precisely determined which knowledge the paramedic needs during the different procedures. Instead of presenting all available information at once the mobile user-interface may only present the currently relevant information due to screen limitations. Users in the health care domain, such as doctors, nurses and paramedics can not give user-interfaces their complete attention because of the fact that they primarily focus on the patient treatment. Therefore mobile user-interfaces have to present the information in a way that all information can perceived unproblematically and quickly. The third concept shows how currently relevant information and additional information can be presented on mobile hand held devices at the same time. The proposed concept can easily be transferred to all medical applications in which the users have to retrieve statical knowledge on clearly defined procedures or algorithms and have to document the patient state accordingly.

6 Presentation of patient related knowledge

As mentioned above due to the special environment conditions in disasters scenarios doctors and paramedics are assigned to more than one patient and this patient may be medicated by more than one single relief unit. In order to be able to medicate the patient accordingly to his injuries or disease the doctor requires all available patient related information. In addition to the patient state the previous treatments which have been performed by doctors or paramedics are of crucial importance. Before all patient related information is presented to the user, however, the paramedic has to ensure, that the digital patient record and the present patient match. On the one hand technical solutions, such as RFID or GPS, can help to find the correct matching, on the other hand the quick presentation of the most important patient related information can be used to check the matching. The more unpredictable and chaotic the present situation is, the more difficult the selection of the correct matching can be. Figure 4 shows how the mobile user-interface can assist the user in finding the correct matching by presenting patient related knowledge.

On the left side of the screen regional information as well as information for the patient relocation is shown. In addition to the unique patient id (in this case *5529*) the last team which medicated the patient (in this case *Team 4*) and the timestamp (in this case *15:26* which indicates the up-to-dateness of the patient related information is presented on the mobile user-interface. The patient history including previous triage decisions and medications is shown on the right side. The presented information depends on the types of patient treatment which have previously been performed. In this case, the patient has not been medicated, the triage, however, has already been performed by the previous team. Therefore detailed triage information is presented to the subsequent doctor or paramedic in order

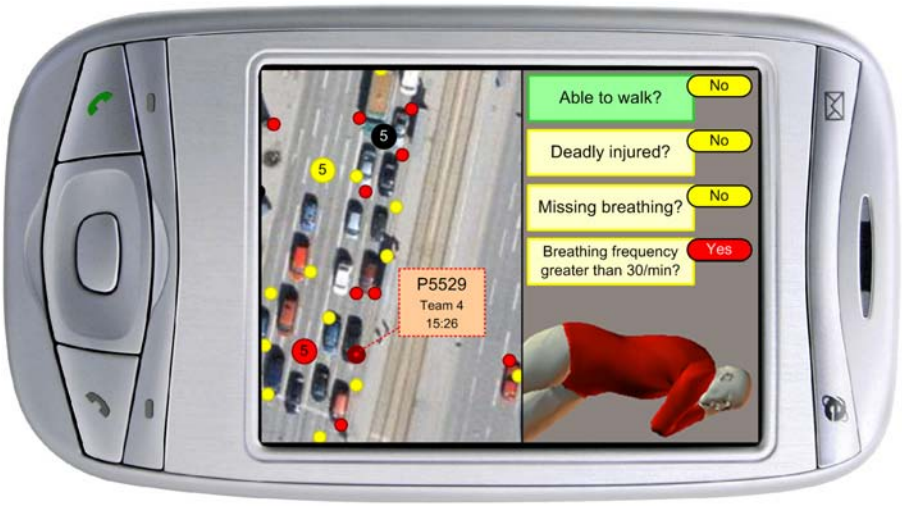

Figure 4: Presenting patient related knowledge on mobile devices.

to enable him to perform the appropriate care. The most important triage information is the triage result which is displayed on the right screen side in addition to the triage decisions. The red colored lying man indicates that the patient is triaged as a T1 patient and has to be medicated immediately (for further information on the different triage categories see [NK07, NDE+07]).

Whereas in the system comprehensive information on the patient, his previous locations, all teams with patient contact and personal data is available the mobile user-interface only presents the currently important extract in accordance with the design choice to only display the most relevant information. The identification can be performed without personal data as well and due to the fact that the patient state in this special environment is likely to change frequently the last information is of particular importance. In more stable environments, such as hospitals, the matching of the digital patient record and the present patient is simpler, furthermore the patient position is more unlikely to change unpredictably.

7 Presentation of peripheral information

The more unpredictable and unstable the environment is, the more the relief workers are depended on additional information on the overall situation. This information includes information on the relief workers, such as quantities, locations, skills and working load, and also information on the patients, such as states, quantities and locations. For the benefit of an optimal resource management and allocation the number of relief workers compared to the number of patients is of crucial importance. The more patients per relief worker are in the disaster area, the less medical treatment is possible, if the relief workers attend to equal

opportunities for all patients. The mobile user-interface presents the peripheral information on the relief workers as shown in Figure 5. In addition to the numerical overview which is shown in the footer the locations of the different relief units is presented. The numerical overview of the relief workers is sorted by the different types of relief workers, units and vehicles, such as doctors, paramedics, ambulance men, emergency ambulances, mobile intensive care units and ambulances, represented by their standardized symbols. Furthermore the relief workers can also be sorted by other criteria, for instance by their current function. In Figure 5 the group of all relief workers who currently perform triage processes is highlighted, besides an unique id and the function the timestamp at which the team started the triage is shown. By presenting the information in different ways the relief workers retrieve a quick overview on the environmental situation and at the same time the operation controllers can trace all teams of interest at a glance.

Figure 5: Presenting information on all locally present relief workers

More detailed peripheral information on relief workers which are moving through the disaster area is presented in Figure 6. Relief units are informed about the paths of other units through the disaster area, which are shown on the left side of the screen. Moreover a list of previously medicated patients is shown in the right side of the screen. This concept of information presentation is similar to the presentation of the patient related knowledge and helps the relief workers to receive information on other teams and thus on the overall situation. It has to be stressed that the local context of this information has not to be provided by the paramedics - it can be created automatically by tracking all teams and patients. As a byproduct the tracing of the paramedics can be used to create a map of access paths to the disaster area and to specific patients. In early stages of the disaster management there is only sparse regional information, the position of nearly all patients is unknown, whereas later in the disaster management process it could be feasible to enrich the mobile user-interfaces with general routing and guiding capabilities.

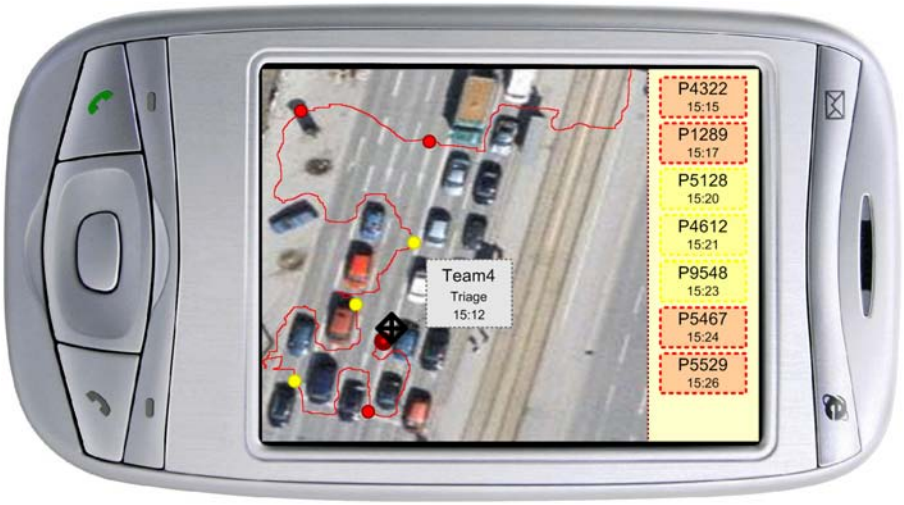

Figure 6: Presenting detailed information on a specific triage team

The patient map has already been used for the presentation of the patient related knowledge. Nevertheless the same map can be used to visualize peripheral information as well, since the peripheral information includes information on the patients' quantity, locations and states. Figure 7 shows our approach to give the user an overview on the overall spreading of the patients. Patients belonging to the same triage category are grouped for the benefit of clarity, if their current location does not differ significantly. This way of information presentation gives the relief workers the possibility to determine where many patients of one specific triage category are located. This is of crucial importance due to the fact that first of all the T1 patients (indicated with red labels) have to be medicated, before the medication of T2 and T3 patients starts. Furthermore the regional spreading of the patients with certain triage categories is an indication for the cause of the mass casualty incident. A bomb explosion, for instance, would lead to a circular spreading of the patients with red and black patients in the epicenter, the patient map shown in Figure 7, however, has no circular spreading and no epicenter. This way of presenting the peripheral information furthermore supports the relief workers in determining potential locations of further injured persons.

These concepts show, that assumptions can already be made in the very early stages of the disaster management process where only sparse information is available. Furthermore conclusions on the environmental situation can be drawn solely from the behavior of the relief units in the unstable environment. Potential reasons for the occurrence of the mass casualty incidence can be drawn from the regional spreading of the patients. Although the underlying database is complex, the concepts show how the peripheral information can be presented in a way that a relief workers can quickly form an opinion about the overall situation without occupying them with complex device handling.

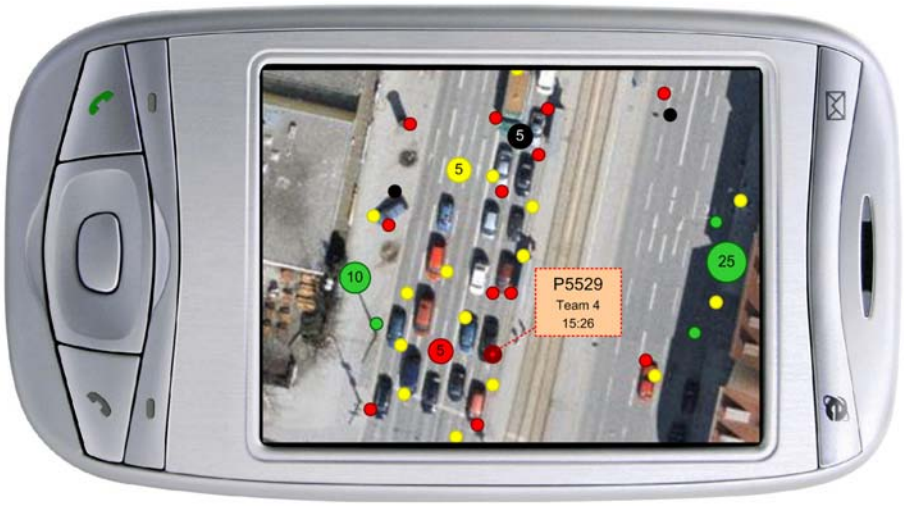

Figure 7: Presenting information on the overall patient situation

8 Conclusion

Pundits may argue, that the concepts for proposed mobile user-interface are quite simplistic. The reason for the concise and clear views on the complex underlying models is the rigid limitation on currently relevant information. Depending on the currently performed task the mobile user-interface either presents static knowledge (e.g. during the triage and patient treatment), patient related information (e.g. before the treatment process) or information on the overall situation (e.g. when the relief workers are currently not medicating any patient). The general concepts base on the experience at which step in the disaster management process which information is frequently required. Information which is usually necessary is shown instantly to the paramedic and only for atypical information the user has to perform more complex interactions. Moreover the concept shows how the adaptivity of user-interfaces can be increased by incidental information collection in the background.

We pointed out, that medical applications differ significantly from non-medical applications. The basic difference is, that in the health care domain user interfaces may not demand the user's complete attention due to the fact that the user primarily focuses on the patient. One of the major reasons why the users reject mobile devices in the health care domain is the too complex and confusing user-interface which can not be used during patient medication.

There are several advantages for each single user when he utilizes the mobile user-interface in disasters. The user can retrieve knowledge which is typically necessary in his concrete situation. Furthermore other units can request information on relief units without interrupting them in the patient treatment. Provided that an acceptance of the application without

reservation is aimed, the introduction of mobile user-interfaces has to lead to obvious advantages for all users. Otherwise some users are likely to refuse the use of the proposed system.

When proposing suitable user-interfaces for the health care domain it is important to offer different types of additional information on the mobile devices. For less experienced users static knowledge is of crucial importance and when using bulky paper based instructions and information material information search can be laborious. Users of all different skill levels need to identify the relevant patient related information at a glance when starting with the medication of a concrete patient, this task is the more complex the more information on the patient exists. Furthermore in the health care domain the medical staff has frequently to be informed on the overall situation in order to facilitate optimal medication for all patients. Mobile user-interfaces for the health care domain which offer all different types of information therefore lead to advantages for the medical staff, including doctors, nurses and paramedics.

9 Future work

The introduction of mobile devices in disasters is challenging and complex. We proposed different concepts for presenting the different types of information, but the input of more complex information has not been considered yet. Furthermore first concepts for the information presentation have been proposed, but our current approach at the moment does not present all available information. The complete implementation of our system, however, will already be more comprehensive than current paper based approaches. Because of the high complexity of disaster scenarios the introduction of mobile devices has to be conducted in smaller steps, the presented concepts is just the first step toward the aspired exhaustive support of medical staff in disasters.

We currently only focus on the design of adaptive mobile user-interfaces, whereas there are many further open questions. On the one hand it is of crucial importance to select robust and resistant hardware and on the other hand reliable and fault-tolerant communication technologies are inevitable. Moreover in other fields well established technologies such as RFID as well as emerging technologies have to be checked on their suitability for disasters. Our prime focus in the future will still be the advancement of the mobile user-interfaces for above-named reasons and the adequate integration of these technologies in our existing concepts.

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