Abstract—This paper presents the physical and digital design of a wireless biomonitoring system meant to be used especially in the prehospital medical emergency response. The handling of many patients with a minimum of resources at major incidents is an immense challenge for the emergency personnel at work on an accident site. New technology such as the BlueBio biomonitoring system, can help emergency personnel monitor the patients and support them in making priorities of treatment and transport of patients. However, if new technology is to be introduced in such a complex and stressed situation it must relate to the palpable aspects of pervasive computing. It must be able to comply with the scale of the situation and still be understandable. It must also be able to comply with change of location and users and yet still be stable, and it must comply with the shifting requirements from the users regarding automation and user control. Our design framework, in relation to the BlueBio monitoring system, approaches these challenges from the perspective of familiarity, medical assessment and person ID/registration of data. We present how this informs and has implications for both the physical and digital design of the current prototype.

Index Terms— Biomedical Computing, Biomedical Monitoring, Design Methodology, Emergency services.

I. INTRODUCTION

This paper describes the digital and physical design of a wireless and mobile biomonitoring system, called BlueBio. BlueBio is intended to monitor injured persons, especially in the prehospital work, in both major incidents (MI) and everyday emergency response situations.

The description of BlueBio will include current status of the work, and a description of the future work. The description of the prototype will be centered around the physical and digital design.

The project, in which BlueBio is developed, is called “IT support in Major Incidents.” It is a subproject of two larger projects: PalCom [23] and Understandable IT [33]. The main purpose of both these projects is to investigate requirements for an open software architecture supporting user’s interaction with pervasive computing world. This possibility to interact with pervasive computer systems is called palpability and is described in more details below.

Fig. 1: Participatory design at a “future lab” session
obtain a common knowledge about the application area. Together they identify needs for new technologies, which are designed and built through iterative and experimental processes. The current design is the outcome of in depth investigation of the user field, including comprehensive field studies and series of meetings and experimental workshops with groups of end users participating. These activities have provided the data, leading to the prototype design described in this paper. The used method and primary results are described in more details in [18], [19], and will not be described in further detail in this paper. On the basis of field studies, meetings and workshops we have obtained detailed knowledge and understanding of the emergency response efforts and structures as such. Furthermore, we have gained an in depth understanding of how the medical emergency response work is carried out in Denmark today. In the following section we give a brief overview of the emergency response process and structure in Denmark, followed by a more detailed description of the technologies at stake in the Danish medical emergency response.

A. Emergency response in Denmark

The response to an emergency is in almost all cases initiated immediately after receiving an alarm call (through the public well known alarm system) (calling 112). When activated, the emergency response resources on stand-by are allocated to the incident site and assisting sites (e.g. hospitals) through the use of the country and/or region specific code of practice. Each emergency situation is unique in the way that the specific incident situation is assessed regarding needs for resources, initially by the receiver of the call in the alarm centre, and later on by the response manager(s) at site.

The larger an incident is (regarding physical spread and/or number of casualties), the more resources (personnel and equipment) are needed and the more complex and difficult it becomes to organize the overall situation and with that also the emergency response. Many different types of emergency response professionals are involved (especially police, fire fighters, medical staff and ambulance staff), and follow the beforehand planned and known Incident Command System (ICS) [9]. In the ICS the roles of the different professionals and their mutual routes of communication are specified, together with directions for physical configuration of the rescue area. The action and communication happen within a certain structured hierarchy, both within each profession and across the different professions. Working and communicating within this hierarchy should have the effect that they all can recognize what to do, who to refer to and collaborate with. Each person can concentrate on exactly his/her task in close cooperation with other professionals involved. Briefly explained the overall division of work between professional skills is as follows:

1) The firefighters are the primary rescuers – they are responsible for getting people out from the primary emergency area and for securing the incident area.

2) The police are the overall responsible professional group.

They establish the cordonning off around the emergency area and are responsible for providing and obtaining routes for transportation of equipment and people. They are also responsible for the registration of all people involved – both injured and non-injured. Moreover they have to take care of the public, the media and the relatives.

3) The ambulance people are responsible for obtaining and maintaining enough available ambulances for the transportation of injured persons to hospital(s) and also for the transportation itself.

4) The medical professionals are responsible for handling the injured persons – the initial assessment, treatment and transfer to hospital. This is often carried out in close cooperation with the ambulance staff.

B. Use of technologies in prehospital medical emergency response

1) Medical assessment

One of the main issues in the medical emergency response work concerns the medical assessment of victims at the incident site.

Medical assessment is carried out by the medical staff and/or the ambulance staff (normally physicians or paramedics) – who examine the patient.

In incident situations the primary focus is on the individual injured person’s condition regarding: If the injured person’s (A)irway is free, if the person is (B)reathing and if there is blood (C)irculation. This is called the ABC treatment concept, and all injured persons are observed and treated with these three parameters as the starting point [10].

At the hospitals or at the general practitioner’s clinic, physicians use many different kinds of investigative technologies to support the medical assessment, such as blood tests, scannings, x-rays and monitors, to support and substantiate their examination and monitoring of the patient. However, in the prehospital medical work it is difficult to use such equipment, and today almost only one type of monitoring equipment is typically used – the Life Pack 12'. This technology is developed primarily for diagnostics, treatment and surveillance of heart failure patients, but is also used for monitoring people with other types of injuries – e.g. caused by a car accident. It is important to stress that it is very stable and trustworthy equipment, but use of it holds some central problems: LifePack 12 consists of sensors to measure a full ECG signal (meaning that several electrodes have to be placed on the body), oxygen saturation in the blood (meaning that a sensor has to be placed on a finger, and a sensor for measuring blood pressure (meaning a cuff has to be places around the arm). These different sensors, placed on the injured person’s body, have only wired connection to the monitor, containing the display. All the wires complicate the work, simply because of their presence, but also the one to one connection between sensor and display means that the monitored data can only be seen if you are just beside the “not mobile” display, which in

1 http://www.emergencymedicaltechnology.com/lifepak12.html
practice means being beside the patient. This has one main advantage in the sense that while observing the monitored data the injured person him/herself can also be directly observed, but the situation also entails constraints. Especially in an incident situation with many injured persons there is not enough equipment to surveil all those who are injured, and there are not people enough to sit beside every injured person to observe the monitored data. Therefore, monitoring equipment is only used for supervision of the most severe casualties.

2) Person id and registration of data

Another important issue concerns identification of persons and registration of different data related to a victim’s injuries or the accident as such.

Depending on the extent of the incident situation, different documents come into play for registering relevant data. In any case the document contains – beside space for the relevant data – a unique id that should count as the temporary person id until the real person id is known.

The document, (called Incident Card) is intended to be filled out continuously for each injured person, starting at the moment they are located and until they are handed over at the hospital. Thus the document has to be tied to the injured person. But in practice the document is not used in MI situations – there is simply not enough time to fill it out.

When several persons are injured triage\(^2\) is carried out. Triage is a process where injured persons are sorted into (four) groups, depending on their needs for or likely benefits from immediate medical treatment. Coloured cards are used to indicate to which triage category each injured persons belong: Red colour indicates need for immediate help; yellow colour indicates that the person can wait a while; green colour indicates that the injuries are not critical and black colour indicates that the person is dead. As with the above mentioned document for registration of data, the triage card also should be tied to the injured person, but in practice this is also not carried out as intended. The only paper document that professionals really strives to fill out in MI situations is an Incident Log. The incident log contains information about which patient is transported to which hospital. This means that it is very limited information that is documented about each injured person – an (interim) ID, two words that describe the injuries, how the person is therapeutically prioritized (the triage) and which hospital he or she is brought to.

3) The familiarity principle

Last – but not least – is the third issue concerning the importance of the users being familiar with the technology they use. This is an important issue for technologies in all situations, but the bigger an incident is the more stressful and chaotic the situation is. In MI situations there is simply no time for trials with technologies and – most likely – errors, and familiarity with technology can only unfold through using it in the everyday work. So, the technology that has to be used in MI situations should also be used – and useful – in the everyday response work.

C. Pervasive computing, palpability and medical emergency response

As it appears above and in [18], [19], use of up-to-date information technology is limited at the incident site in the medical emergency response work, carried out. However we move towards a society where pervasive computing technologies are becoming integrated in our everyday life, through extensive use of especially still smaller microprocessors, wireless technologies, increase of bandwidth and growing quantity of different mobile devices and displays. So, when considering and discussing future technologies to be used in medical emergency response the pervasive computing angle is important to implicate and investigate.

1) Palpability

Palpable computing is a new perspective in pervasive computing. The concept was introduced with the PalCom project [23] and deals with the use aspects of pervasive computing, in the way that palpability indicates that IT-systems must be capable of being noticed and mentally apprehended, that palpable systems support people in understanding what is going on at the level they choose and that palpable systems support control and choice by people.

More specific palpability of pervasive computing systems can be characterized by the following concept pairs, where the left-side concepts characterize ambient computing and the right side concepts characterize palpable computing [23].

Invisibility \(<\rightarrow\ \text{Visibility}\)
Scalability \(<\rightarrow\ \text{Understandability}\)
Construction \(<\rightarrow\ \text{Deconstruction}\)
Heterogeneity \(<\rightarrow\ \text{Coherence}\)
Change \(<\rightarrow\ \text{Stability}\)
Automation \(<\rightarrow\ \text{User control}\)

The notion of palpability is in different aspects further elaborated in [1], [4], [5], [16], [24], [29].

2) IT support in major incidents and palpability

Regarding the work in the current project - “IT support in Major Incidents” – we focus on especially three of the challenge pairs, listed above:

1) Scalability \(<\rightarrow\ \text{Understandability}\), where our focus is to investigate how the same applications can be used (and useful) in both small and large scale situations, in a way that the understandability of what happens in the application is maintained, even when the use of an application is scaled up.

2) Change \(<\rightarrow\ \text{Stability}\), where our focus is to investigate how stability of systems of technologies and connections between systems of technologies are obtained and maintained in locations with a high degree of dynamics. Not only regarding mobility and amount of people and technologies, but also in situations which are stressful, unexpected, and where the settings are unknown.

\(^2\) http://www.answers.com/topic/triage
3) Automation <-> User control, where our focus is on what can happen and has to happen automatically in different extents of dynamic, stressful, unexpected, unknown settings and what can be/has to be controlled by the users.

II. RELATED WORK

In this section we present related work within the three areas: Medical Assessment, Person-id and registration of data and the Familiarity Principle.

Within the first area - the use of monitors for medical assessment at site – The CodeBlue hardware and software platform for medical sensor networks is of special interest, and is similar with our project, since this work is also related with emergency response and is intended to be used both at site and in related hospitals. Another similarity is that the CodeBlue work focus on development of a wireless communication infrastructure, but CodeBlue especially addresses the robustness and security challenges and requirements that are of vital importance within emergency medical settings [21], [22], while we focus on the palpability aspects – or PalCom challenges – as described below in III. Moreover we do both experiment with use of data from different types of sensors, e.g. pulse oximetry and electrocardiogram (ECG) sensors [12]. Also [30] investigate on how to do continuously medical monitoring by use of wireless microsensors, and here the key issue is the portability aspect, meaning wires and heavy batteries are not desired. [8] has investigated the use of 3G networks for wireless transmission of different types of data (patient’s video, medical images and (ECG) signals) between an incident site and hospitals, to enhance the possibilities for trauma specialists at hospitals in supporting the prehospital trauma care.

Regarding the person-id and registration of data several studies focus on these aspects: Today’s problems with the use of paper-based technologies are described via concrete incident situations in [31], [32]. [15] Describes a speech input and voice output prototype, to be used in the prehospital care, with a syntax that enable the speech recognition system is described, to interpret patient conditions, treatments, triage and patient transport requests. [7] gives an overview of research on, among other factors, emerging information technologies to support patient tracking, monitoring and medical care. Of special interest is a vital data monitoring system, developed to monitor soldiers, but which also could be used within the healthcare area, especially in disaster medicine. This monitoring equipment, called the Personnel Status Monitor (PSM) is combined with a global positioning system telling where the monitored person is [27].

Regarding the familiarity principle several studies stress that those who work within emergency response – and especially in mass casualty or disaster situations – have to know what to do and how to do it. Many studies take concrete experiences from mass casualty incidents as their starting point, e.g. [11], [20], [25], [26], [31], [32] and are theoretically elaborated, in e.g. [28].

III. DESIGN OF BLUEBIO – DESIGN FRAMEWORK

Given the recognized issues concerning the medical emergency response work, described above, and the research on palpability within the PalCom project [23], our research group – in close cooperation with the users – decided to get into development of the BlueBio biomonitoring system.

The two main objectives are:

- From a medical user perspective to get a biomonitoring system that is easy to handle and to work with and can collect data that informs primarily about the most vital parameters (meaning indicating an injured persons ABC status). Data should be available over distances and for all persons who might need them and when they might need them.
- From a research perspective to develop a prototype, that enables us to carry out experiments with the PalCom challenges scalability/understandability, change/stability and automation/user-control, as input to the open PalCom Architecture [23].

This has lead to the design framework, shown in Table I below, where each cell is further described in the following.

<table>
<thead>
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<th>TABLE I DESIGN FRAMEWORK</th>
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A) Medical assessment / Scalability – understandability
The daily use situation for the biomonitor is for monitoring all patients at smaller accidents, where the biomonitor transmits information regarding ECG, Oxygen saturation and breathing. In these situations, detailed data is requested by the medical staff, both at site and at the receiving hospital. However at major incidents where many patients are monitored, the level of information detail should be able to be downscaled, to the benefit of monitoring more patients and thus supporting the overview by for instance the medical coordinator on site and/or the staff at the Acute Medical Coordination centre and in the emergency department.

B) Person ID and registration of data / Scalability – understandability
Person ID is a difficult task in emergency situations if people are unconscious, confused or dead. Personal ID’s found in wallets can be borrowed or even stolen, and witness descriptions can be biased by the turmoil of the situation. However it is necessary to have a unique ID system to support continuity through the emergency response.
Using the Biomonitor for ID is an obvious possibility, however it requires adequate precautions to secure that a specific person's ID is tied to a specific biomonitor. This can be done by the medical professionals specifically pairing ID and Biomonitor by a specific interaction.

Furthermore, there is the question of what kind of ID is preferable. On site the medical personnel use descriptions like “the one in the red shirt”, “person lying next to the blue car” or “guy with the chest injury and the broken leg”. However this information does not stand for larger scaling up, and implicates other solutions to be found such as uniquely generated numbers or precise positioning with the ability to keep track of the patient.

Attaching other types of data like speech annotations, pictures and/or video streams could also contribute both to the medical assessment and to the scalability/understandability dimensions.

C) Familiarity principle / Scalability – understandability

In order to be operational at major incidents, regarding working structures and processes, equipment, tools and instruments must be familiar to the medics through daily use. This has profound implications for interfaces and interaction design which must be able to scale and be understandable and useful for both smaller accidents and major incidents.

D) Medical assessment/ Change – stability

The biomonitor is intended for use not only on site, but for monitoring the patient during the whole period from the monitoring starts at the accident site, during transportation to the hospital and at the initial interventions at the hospital. This requires that even though the patient is moved and the wireless connections change during transportation, the information flow should be stable, and in the eventuality of periods with no connections, the history of data should still be available when connection is established again.

E) Person ID and registration of data / Change – stability

The applied person ID must keep stable throughout the whole treatment period ranging from the accident site until initial treatment at the hospital – and preferably during the whole stay.

The ID must remain the same, even though the surroundings change. In current praxis, patients can have applied several ID numbers during the different interventions from the accident site until treatment is finished.

F) Familiarity principle / Change – stability

The interaction with the biomonitor must also comply to the fact that different professionals ranging form the medics on site to for instance a nurse at the hospital, need to be familiar with the biomonitor.

G) Medical assessment / Automation – user control

When monitoring patients on site, the medical staff will want to read information from specific patients. This calls for explicit user interaction, where the medical staff can choose source and level of information from the biomonitor. However, when monitoring of a specific patient is not required, it is still desirable that the streamed information from the patient is stored and thus accessible at a later period of time. Automation of this process is required, as well as an explicitly indication that this information is available is important knowledge for the ambulance people and/or the staff at hospital.

Storing of information and conveying of the information of availability should be accomplished by the system automatically. Nevertheless, in case of breakdowns, user control is essential for re-establishing connections and for assessment of the extent of the breakdown level or for checking out if signal disruptions stem from the technology or the patient.

Breakdowns should not be handled by the medical staff at the incident site, but by persons remotely, e.g. at the hospital. These can survey the biomonitors in use and will be able to recognize and handle breakdowns (contingencies).

H) Person ID and registration of data /Automation – user control

The ID should be transmitted continuously together with the monitored data or other registered data. However, if doubt occurs regarding whether the patient has the correct ID or whether the monitor is transmitting from the right patient, it should be possible for staff and personnel in the vicinity of the patient to inspect the ID and biomonitor to ensure the correct correlation between ID, patient and biomonitor.

I) Familiarity principle / Automation – user control

When the biomonitor is mounted, the transmission of data and ID should begin instantly. Reading of ID and data can be done on various devices ranging from cell phones, pda’s, laptops, televisions etc., containing our open architecture. The biomonitor software should be able to detect what kind of display is requesting to be used, while on the other hand, the user should be able to choose the format and level of information she/he wishes displayed. This kind of interaction must be familiar to the users in relation to scale and mobility.

IV. BLUEBIO – A USE-SCENARIO

The BlueBio biomonitor is intended for daily use by the medic(s) on the accident site, for monitoring the condition of the patient regarding airway, breathing and circulation. The biomonitor is wireless and approximately has a size of 150 x 100 x 18 mm. The underside of the biomonitor consists of an selfadhesive strip which when moved, reveals 3 electrodes and activates the BlueBio monitor. The selfadhesive strip of the packaging has an RFID tag with an ID number which couples the strip to the biomonitor, so a medic with a scanner can read the RFID strip on the patient, and receive the corresponding data from the BlueBiomonitor. (The RFID strip is used for placing on the patient in the same way as luggage strips are placed on suitcases at the check-in desk at airports).

When the medic arrives by a patient on the accident site regardless of whether it is a small accident or a major incident, she takes out the biomonitor from her medic bag. She seals the packaging surrounding the biomonitor, takes of the selfadhesive strip and places it on the chest of the patient. The ID strip with the RFID tag is placed on the hand wrist of the patient if possible.

The patient is now monitored. If the medic wants the specific reading of the patient’s data, the medic uses an RFID scanner connected to her/his display to read the ID tag on the
patient and the data appears on her screen. The detail level of information is high in the default setting, but can be reduced by the user. If it’s a major incident the patients will be gathered at the triage and treatment area and placed according to the triage principle, earlier described. In this situation the biomonitor supports the overview for the people watching over the triage area, by alarming the personnel if major changes in the monitored data take place.

Figure 2: Placement of the BlueBio monitor

The personnel is notified with both a visual indication from an alarming device on the patient and a notification on the medical professional’s personal device. The alarming device, a device with a significant blink, is placed on the patient on arrival at the triage and treatment area and is paired to biomonitor by using the RFID tag on the patient.

In most incidents the majority of patients are transported by ambulance to the hospital within the first hours. However, it is crucial to organize and structure the distribution of patients between the hospitals to prevent overburdening the emergency departments. This is done from the AMC (Acute Medic Coordination).

The assessment regarding which patients are to be moved first is done by the Medical Coordinator at the accident site together with the AMC. At the AMC they can monitor the patient/biomonitor on large displays, and together with the Medical Coordinator the AMC can coordinate which hospital is relevant and has capacity for the specific patient.

As the patient is carried into the ambulance, the ambulance manager on the accident site annotates the ID and to which hospital the patient is transported. In the ambulance, the ambulance personnel can monitor the biosensor signals on their monitor when having read the RFID-ID tag. The biomonitor information is simultaneously monitored at the AMC, who are also notified when the ambulance people read the RFID-ID tag, thus indicating that the specific patient/biomonitor is in the specific ambulance.

At arrival at the emergency ward, the RFID-ID tag is read by the staff at the ward, indicating for the AMC the position of the patient and making it possible for the staff at the ward to monitor the biosensor information.

At this point, it might be relevant for the hospital personnel to exchange the BlueBio biomonitor with more specialized equipment; however it is possible to keep monitoring the patient with the BlueBio biomonitor, if wanted.

V. THE DIGITAL DESIGN

The BlueBio system is designed for use in Major Incidents; this is reflected in the digital design by allowing as much flexibility as possible and at the same time providing robustness when used. The biomonitor collects biomedical signals from the victim's body when placed on the victim. At the moment the biomonitor used in the prototype measures ECG.

The biomonitor is comprised of the following main components:
- Bluetooth module [3]
- ATMEGA8L [2] microcontroller including a A/D converter
- Analogue amplifier and filer used to normalize the ECG

The biomonitor is constructed to use as little power as possible. This power restriction has influenced the choice of components. The microcontroller is only 8MHz and thus do not have the power to handle the infrastructure, further more the Bluetooth devices available when we began the project were not able to handle scatternets and we did not want to limit our prototype to 7 devices, as is the limit in a piconet. The biomonitor communicates using Bluetooth as it provide a robust transport medium in the 2.4 GHz band and the throughput of Bluetooth meets the requirements to transmit an ECG signal. The current biomonitor used in the prototype provides less good support for scaling up the number of biomonitors used, due to the Bluetooth hardware used. Bluetooth as a communication was chosen because it was the only descent standardized low power RF technology available at the time when the prototype were constructed.

In a Major Incident the normal communication infrastructure might not be available. For this reason, the BlueBio prototype system is built in such a way that the professionals involved in the rescue effort automatically bring the infrastructure to the incident site. The infrastructure for the BlueBio system consists of base stations. These base stations
communicate internally using WIFI to form an ad hoc network, and are equipped with Bluetooth radios. The base stations are used by the biomonitor as a contact point making it possible for a much further distribution of biomedical signals. In this way the base stations have two responsibilities at the incident site. They create an ad hoc infrastructure that handles transmission of biomedical signals and they act as contact point for the biomonitor. An example can be seen in figure 3.

Fig. 3: Deployment figure.

The base stations have two purposes at the incident site.

First they act as contact points for the biomonitor, and since the biomonitor is using Bluetooth, the range is limited to around 100m. To avoid using scarce power resources, such as battery, it is desirable not to let the biomonitor handle the infrastructure even though it might be possible.

Second, the base stations at the incident site create an ad hoc network, through which they are able to distribute the signals received from the different biomonitors and thus make them available on each of the base stations. The availability of the data on each base station, allows the professionals at the incident site to view data from all biomonitors at the incident site. This can either be done using Bluetooth or WIFI.

To identify patient RFID is used, as previously mentioned. The RFID hardware consists of the following parts:

- F2M03AC2
- KS-RDH-M1

The RFID scanner at the moment connects to the base station using Bluetooth. Though the base station the information read by the RFID-reader is send to the distributor, as the RFID tag contains the address of the biomonitor it came with, the system can identify the patient and send the physiological signals to the paramedic.

VI. THE PHYSICAL DESIGN

The aim of the project it not to end up with a physical product. However, for two reasons we are focusing on the physical design:

1) Health care personnel are very “hands on” in their approach to technology. Consequently in order to test out use situations, we have prioritized to develop very high end prototypes.

2) The developed software prototype is intended to be used in very dynamic settings. The users are busy using their hands while doing their medical job in a very stressed situation, and “normal” handheld devices might not be the best solutions. So, focus also has to be on the physical aspect, “simply” to get new ideas for future physical design.

We describe prototypes in terms of [17] horizontal and vertical prototypes, in relation to the graph shown in fig. 3.

A vertical prototype is a prototype with functional qualities, while a fully horizontal prototype has features such as surface and material qualities. In the project we have worked with a parallel process between fully functional (vertical) prototypes and high end horizontal prototypes. As the project has moved on, more and more functional properties have been added to the horizontal prototypes and more and more material qualities have been added to the vertical prototypes.

In the following, the basic issues regarding the physical design such as material qualities, surface qualities, interface and interaction are related to medical assessment, person ID and registration of data and the familiarity principle.

A. Medical assessment

For medical assessment the biomonitor must be attached to

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1 http://www.datasoft.se/class2modulewithantennaf2m03ac2.htm
2 http://www.meshedsystems.com/3 Produktd/prod_modul_m1.htm
the patient. In order to achieve the ECG signal, there must be a close connection between the electrodes and the body, which is typically established by a gel. The biomonitor has three electrodes placed with a mutual interspaced distance of approx 10 cm. on line or as a triangle. It is important that the material is flexible enough to follow the organic curves of the body ranging from small children to grownups. Also, there are significant problems with placing the electrodes due to body hair, moisture, wounds etc.

To obtain the most optimal ECG signal the biomonitors should be placed on the chest region, but because the biomonitor then is hidden beneath clothes as well as blankets it may not be visible for others. This implicates the need for another visible device placed on or beside the patient, in order to show that this specific patient has a biomonitor and also maybe indicate visually changes in the patient’s condition and/or give visual alarms. One of the PalCom challenges concerns automation/user control. When mounting the biomonitor on the body of an injured person the user – by this action turns the biomonitor on – an explicit action, controlled by the user, prompts an automatically action.

One of the PalCom challenges is that palpable devices should comply with scalability. The same device used for smaller incidents such as for example traffic injuries, should also be used at major incidents with maybe fifty or more patients. This has consequences regarding transportation capacity if a medical professional has to bring 20 or more biomonitors with her/him. Thus a biomonitor should be as light as possible, take up as little space as possible and be easy transportable.

Another issue is if the biomonitor should be disposable or reused. If the biomonitor is to be reused, the surface must be cleanable and the electronics should then be well protected. Preferably, a composite device would make it possible to reuse the core electronics while the rest would be decomposable. The external visible device which not necessarily gets in direct contact with wounds should have a surface suitable for cleaning and reuse implicating a smooth surface without nooks and crannies.

B. Familiarity

The familiarity principle was mentioned previously. One of the strongest features regarding the existing LifePack 12 is that the professionals are familiar with this instrument. They know what to expect, how to react when it malfunctions and they are familiar with the technology – and not only in connection with use at accidents, but also at the hospital wards. The healthcare personnel mention this as a main feature, regarding use of equipment at major incidents. In an
ultinate stress situation they must be perfectly accustomed to the devices and instruments which they are using. As mentioned earlier, there is not time for learning use of new equipment, or to tamper with even simple things as for example new packaging systems for sterilized instruments.

The notion of familiarity relates to three issues regarding the biomonitor. First and ideally, the biomonitor should become a device which is routinely placed on the patient from the initial assessment and treatment and kept on the patient may even through the whole treatment period, including stay at the hospital ward. Thus, the biomonitor must be very easy to handle and to place on the body (in order to become routine). Packaging of the monitoring device should be easy to do and a successful placement of the biomonitor should be exposed through visual feedback directly, before the biomonitor is covered with clothing and blankets again. Successful placement is in these terms related to receiving a readable ECG signal and that the biomonitors Bluetooth device is transmitting the signal properly.

Secondly, the biomonitors signal device (placed externally on clothes or blankets) should have the same qualities regarding handling, placement and material qualities as the core biomonitor device.

Third the visual feedback from the signaling device should have a character recognizable by the personnel, meaning that they should be familiar with the feedback from similar equipment.

C. Feedback

The medical professionals want three types of information from the signaling device: 1) The biomonitor is working properly, 2) the state of the patient (stable – worsening – getting better), and 3) and they want the device to provide feedback when reading the display in order to make sure that they are receiving information from the correct patient.

Feedback in general at major incidents can be provided acoustically, tactile and/or visually. However, acoustic feedback is at risk of not being heard in the general turmoil of an accident and is also at risk of aggravating the stressful situation of the patients and the medical staff. Tactile systems lack some of the same characteristics, as just mentioned, such as risk of not being noticed, or having to have a character so intrusive that the tactile response is more of a nuisance than help. Visual feedback seems to be the most promising, but line of sight is a fundamental requirement and can only be used at short distances.

Light diodes in a signaling device, must be visible in strong daylight indicating for example flash diodes. However, at the same time it should be taken into consideration how to reduce the exposure of the light to the patient. The diodes need to be protected from unintended jolts and strokes and the covering glas/acrylic must be resistant to dirt and scratches. The ultimate placement of a signaling device remains to be tried out in our participatory design process but we are working with two candidate placements. Firstly, the patients head will in most cases be visible indicating that a placement here would be natural. However, the patient might move the head either in response to pain or in order to keep an eye on what’s going on, thus risking covering the line of sight, or provoking the device to fall of by fast shaking movements. In respect to this, a placement on the body and most likely on the surface of a blanket seems be the natural choice.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we have shown how we through a participatory design process in a multidisciplinary research team, have identified some significant challenges regarding the physical and digital design of the BlueBio biomonitor.

By taking point of departure in three main issues in the medical emergency response (medical assessment, ID and registration of data and familiarity) and focussing on three of the PalCom challenges (Scalability-understandability; Change-stability; Automation-user control), we have introduced a biomonitor with promising features for use in both small and large scale accidents. The research has also provided important input for the PalCom open architecture software necessary for making palpable (healthcare) systems.

The biomonitor is still work in progress. The current BlueBio can read and transmit a 3 point ECG and connect to WIFI, GPRS, EDGE and other Bluetooth devices through a locally established infrastructure of basestations. Through experiments with our vertical and horizontal prototypes together with end users, such as emergency medical professionals, ambulance personnel, hospital staff and fire fighters, we have been able to identify important issues for our current and future work. We are currently experimenting with sensors providing information of blood oxygen level and sound and frequency of respiration, necessary to carry out a full ABC medical assessment. However, we have already identified a range of problems connected to non visible wireless connections, and are currently working with crucial issues such as how users identify of connections between devices, when the connections are wireless.

Furthermore we are working with issues regarding ID, for example how to improve the identification of victims using digital media and how this ID can be used effectively from the initial stage of the accident until treatment is provided at the hospital. Early experiments in the project showed that identifying injured persons is not only carried out by use of numbers. Numbers – or other types of unique ID’s are used (and should be used), but, when several people work in collaborative, dynamic settings with injured persons, they do not recognize or speak about injured persons by use of numbers – they use other types of ID mechanisms, like descriptions of age, hair colour, damage and damage mechanism and/or where the person was situated when found. These observations – made during experiments – have lead to focus on use of different types of ID’s.

Positioning is also a core issue we have to deal with in our future work – it does not make sense to be able to monitor people over large distances if not being able to recognize
where they are.

We are currently working on the third iteration of the physical design which will result in 10 BlueBio monitors to be used in future laboratories [6], which will provide further input for the PalCom software open architecture [23]. In this process we will also get into connections and dependencies across the different palpable challenges pairs; e.g. how Scalability-understandability and Automation-user control are mutual related.

ACKNOWLEDGMENT

We thank our colleagues in the PalCom project and the pre-hospital effort in Aarhus. We also thank the engineers S. Kucharski, L. Kubala and M. Byczuk, who developed the first version of the biomonitor system.

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