EMS Coordination in Large Scale Emergencies Using Automated Patient Monitoring

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***Abstract*— In large scale emergencies with very limited work force it is difficult to provide best possible care for all the patients. In these circumstances one has to concentrate to the patients that need the care most and there is usually not enough human resources to monitor those patients that do not require immediate medical care. In this paper we describe an automated monitoring device combined to an automated emergency medical care documentation. Based on the documentation system a coordination information system is created. The coordination system monitors patients, resources and supplies facilitating decision making in the coordination process.**

I. Introduction

Emergency medical care is a field where workers face rapidly changing and stressfull tasks daily. Treating a critically injured or otherwise emergent patient requires prompt action and decision making. As the workers have their hands full treating a patient, there is not much time for documenting this treatmet.

Current documentation is mostly based on paper forms with some exceptions such as ECG (Electrocardiogram). The very limited time for filling these forms can result in lack of documentation in cases where they would be most valuable. Using an automated documentation system that can do a more detailed electronic documentation that can then be transmitted to a hospital system can both save time and decrease errors.

Coordinating EMS crews in disaster situations is not easy. The goal is to deliver as good medical care as possible with limited resources to as many patients as possible. This process requires dividing the workload among the crews as well as prioritizing the care so that it benefits the largest possible part of the patients. This means that the person in charge of coordinating the relief effort has to have an up-to-date knowledge of the whole disaster, patients, medical resources and several other factors. This article shows how the EMS documentation system can be used to implement an information system that can provide concise picture of the disaster scene for medical care coordination purposes.

The automated EMS documentation system has been presented in earlier papers and the implementation and security of the system has been described in detail [1].

II. Documentation System implementation

The documentation system is based on an official Finnish SII (Social Insurance Institution) paper form that paramedics have to fill for every patient they treat. Simplifying the documentation process, written data is transformed into a digital form and all measurement values are automatically acquired and viewed by the system.

The documentation system is implemented with visual programming language LabVIEW [2]. The language offers easy adaptation of measurement devices with different kinds of wireless communication protocols (such as, Bluetooth, WLAN, WiFi). Visual program consists of *virtual instruments*. Virtual instruments can be quickly replaced by other ones without wide changes in the whole program code. Therefore, an application version with specific functionalities and UI properties can be implemented for a new situation and requirements of it. The requirements can be, for example, specific UI layout for different user roles, or, different kinds of emergency situations (minor or major incidents, etc).

GPS is a satellite based system, where satellites transmit time and position information to a device that can receive the signal. Given three or more satellite signals, the device can calculate accurate position in the coordinate system.

This information can be used to create a map with locations of each individual EMS unit. Location information of both the EMS unit and known patients is then used to estimate the workload of the unit and the need of additional resources.

RFID (Radio Frequency Identification) has become widely discussed tehcnology lately. It is not a new technique, applications utilizing RFID have been around for decades. Most common areas where RFID has been used include industry logistics and traffic, e.g. paytolls. RFID technology utilizes tags and readers that can read tags without a line of sight. RFID Tags can be either active or passive [3]. An RFID tag can contain information and some tags can be written to. Memory capacity of RFID tags vary, up to 1 MB [4].

III. Wireless short distance communication

In our documentation system, wireless communication between measurement devices (slaves) and a collector device (master) are based on Bluetooth communication.

In the system implementation, we have two kinds of Bluetooth communication devices: *push* (read-only) devices and devices supporting bidirectional communication. A push device only transmits acquired data to the collector device and, therefore, it is not possible to control the device programmatically. In bidirectional communication, data flow both

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ways enabling a user to control a measurement device more efficiently. For example, desired sample rate of a measurement device can often vary from case to case. Furthermore, some devices are able to transmit data in different units of measurement, which makes it much simpler to receive data in required format (by sending control commands to the device) than programmatically modifying each measurement result.

At this time, we are implementing a new prototype of the documentation system that supports ZigBee communication. Bluetooth is alleged to be more unreliable [5], [6] than ZigBee communication standard (IEEE 802.15.4). The usability of Zigbee comes from its ability of quick self organizing data network and low power consumption.Thus far, the lack of ZigBee devices for medical purposes sets restrictions to our research.

IV. Patient monitoring device

In a large scale multipatient emergency there usually are too many patients for individual surveillance by the medical staff. To improve the patient monitoring possibilites we have designed a device that has a wireless (ZigBee) connection to the EMS documentation system. The device measures patient's heart rate and blood oxygen saturation using an oximeter placed on the patient's finger. An oximeter can be implemented in a rather small space, see [7] for example. The EMS documentation system facilitates following the patients condition when there is not enough personnel for individual follow-up. A change in heart rate or oxygen saturation that exceeds some predetermined treshold would create an alarm on the EMS documentation system that would draw the attention of the EMS crew.

The device also records the patient's position using GPS coordinates. The size of the GPS chip is not a problem, the mallest chips on the market are smaller than 4mm*4mm [8]. The GPS antenna however requires some space, but wrist watch implementations have been available a number of years, for example, from Suunto. In situations in which GPS signal is not available (indoors), relative location to other monitoring devices and the EMS documentation system can be calculated using the technology familiar from avalanche beepers.

ZigBee modules have become rather small in size and also affordable [9]. With low power consumption and small size they fit our purposes very well. One of the main usages for these modules are sensor networks like the one we have. In our network the patient monitoring devices connect to both the EMS documentation system and other monitoring devices.

In our design the oximeter, ZigBee module, RFID tag, and GPS module are all included into one device with the shape and size of a wrist watch. The device also has an emergency button that the patient can push to draw attention of the EMS staff. A patient classified green on the triage scale can be adviced to use the button if she starts to feel worse after the initial diagnosis. The device can be attached to the patients hand or feet with a fabric welcro strap.

The hardware design and implementation is currently being done in the hardware lab. Initial results show the concept feasible. The biggest challenge at the moment is the power consumption of the GPS module that restricts the battery life to 6-8 hours. However, as we can assume that the patients will not move about very much, it seems that it is possible improve the battery life by decreasing the GPS calculation frequency.

V. Conclusion

Sometimes in emergency medical care minutes can make a big difference. The first five minutes can contain more decisions and procedures than the rest of the treatment period all together. It seems obvious that the patient is the main priority and there simply is no time for documenting the treatment adequately.

Our solution uses state-of-the-art technology to automatize large part of treatment documentation. Automatic documentation will give the paramedics more time to concentrate on the patient and a more thorough treatment history to refer to later on. The hospital will get a thorough documentation of pre-hospital care and medical research can have extensive database of treatment data. This data can help improve practices in emergency medical care.

We have paid great attention to make our system as secure as possible without sacrificing usability. The core of our security solution lies in a PKI infrastructure that utilizes smart card technology in authentication.

The EMS documentation system also serves as a platform for coordinating relief effort and monitoring patients in large scale accidents. Using the patient monitoring devices the exact location, triage classification and key vital data can be collected automatically. This enables creation of concise view of the disaster scene and effort coordination based on that. It also enhances patient safety as it monitors patients that cannot be monitored by personnel and the identification of patients becomes more reliable. The system can alert if the state of some patient changes considerably.

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