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AN AMBIENT HEALTH MONITOR FOR THE NEW GENERATION HEALTHCARE

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ABSTRACT

Without an iota of doubt, the healthcare industry is the largest one across the globe not only in market value but also in profusely and powerfully applying a bevy of robust and resilient information and communication technologies (ICT) in order to do away with scores of manual tasks. As known widely, manual implementation and operation are liable for errors and faults. Being a life-critical domain, every promising and potential technology is being readily recognized and rewarded in the healthcare field. Precisely speaking, the hot healthcare field has become the dominant and prominent ICT-driven discipline today and tomorrow is still brighter. Electronics and instrumentation disciplines are also tremendously contributing for the unprecedented success and growth of the healthcare domain. The extensive leverage and usage of competent techniques, tips and tools for bringing in comprehensive and compact automation, optimization, and transformation in the healthcare landscape has been going successfully for a long time now. And this positive and progressive trend is all set to go further broader and deeper with the easy availability on-demand, online, dynamic, real-time, and adaptive computing systems. The prevailing trend clearly indicates that there would be myriad dramatic and drastic changes in the healthcare field with the insights-driven adoption of information technology (IT) and nanotechnology together and hence the ensuing healthcare systems would be cognition-attached, cloud-based, process-centric, service-oriented and knowledge-driven.

With the persistent increase in aging population especially in developed countries, heightened healthcare costs, error-prone healthcare operations and the maturity and stability of medical care technologies, IT-enabled medical care is all set to reach newer heights in the days to unfold. This paper describes a prototype medical system, which could effectively monitor any patient's health parameters such as pulse, blood pressure etc., administer salubrious drugs automatically and inform the doctor and the caretaker about the current conditions of the patient in time. All kinds of interactions are controlled ubiquitously by using an Ambient Assisted Living (AAL) system. The Open Service Gateway Initiative (OSGi) standard and one of its open source implementation is prescribed as the middleware for effectively discovering, connecting, and mediating all kinds of Ambient Sensor devices. In order to deliver the prescribed drugs dynamically to the patient, a new device has been freshly designed and we have named it as "Ubiquitous Drug Injector (UDI)". In addition to this, a pervasive device is being provided for each patient and this device could receive inputs from the ambient devices and enable in correctly inferring the condition of the patient. The insights retrieved, processed and analyzed facilitate in administering appropriate drugs well in time. The whole system designed and prototyped is a highly scalable healthcare system with varying control flows. This work lays a strong and sustainable foundation in evolving novel techniques for next-generation healthcare.

Keywords: *Ambient Assisted living (AAL), Healthcare, Knopflerfish, Open Service Gateway Initiative (OSGi), Wireless Sensor Networks (WSN)*

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1. INTRODUCTION

With the advent of rapid industrialization came great advances in economy and products of higher benefits. Along with these crawled the problems of pollution, contamination and global warming. This in turn has its own ill effects of increased disease rate and impeding health conditions. In this situation individual attention to the patient has become almost impossible in many medical centers. This led to the rise of Ambient Assisted Living systems (AAL) [1-9] in which smart devices help the patients to attain their needs, and the doctor to know about the intensity of the illness. Nayat Sánchez-Pi and José Manuel Molina [10] designed an architecture and developed context-aware Applications to build an intelligent home. The advent in digital circuits and telecommunication forces a middleware for intelligent environments through internet is explained in [11]. Augusto *et al* [12] has given a detailied state of art about AmI and SmE various participating core disiplies and discuss human machine interaction. Furthermore it also encourages various inter and intra discipline researcher (communication , computer, instrumentation and robotics) can go for a collaborative work to build smart environment in future. Rui Pedro Marques [13] has presented a solution in ubiquitous computing environment with a suitable mechanisms to reduce the delay in taking the medication with relevant alerts.. Venkatesh *et al* [14] implemented a smart environment to facilitate entire medical procedure in a hospital ICU where the timely decision on treatment would be better solution. Furthermore the same author [15] developed a standards-based ambient healthcare system. It argues that, this system improve the living conditions of humans being and is a great gift for the elderly, debilitated and disabled. Here we discuss about an efficient mechanism which can monitor patients, administer drugs and instantiate updates to the medical practitioner and the personal caretaker of the patient without requiring any human intervention. One more major requirement of such a system is that the system should be highly scalable so that it can handle additions of newly admitted patients. In the following paragraphs the technical requirements and the logical build of the system is explored.

1.1. Technologies used

Open Service Gateway Initiative (OSGi) has been serving as a very effective middleware for sensor based wireless networks and pervasive infrastructure for quite some time. The OSGi framework is a java based complete dynamic component model. In order to put this into practice this we make use of a tool called Knopflerfish which is an open source OSGi framework. Knopflerfish consists of an interactive GUI for controlling and installing various bundles to be executed in the framework. In order to measure the vital body specifications of the patient we use Zigbee enabled sensor devices which are connected together by the means of a Wireless Sensor Network (WSN). This is a localized network extending regions only unto the patient's Personal Data Assistant (PDA). In order to implement the web service we use Apache Tomcat 6.0 as the application server and MySQL as the database. The Integrated Development Environment (IDE) used for creating the OSGi bundles is Eclipse Ganymede where we use the OSGi plugin and the equinox deployment configuration. The web service is developed in Netbeans IDE 6.0 which is a multiple platform Open source Integrated Development Environment.

1.2. Ubiquitous web services

Apache Tomcat is an open source implementation of java servlet and java server pages (JSP). We can host numerous JSP based applications and use the servlet to host it. Here we create a JSP scriptlet which can function to our requirement. Scriptlets are faster for monitoring small amount of data. The database that we use here is MySQL database which is an open source database capable of MD5 encryption. This database is selected due to its lightweight and thus runs in lesser hardware too. The front end of the web application is made up of normal HTML and CSS so that it runs on all the browsers without compatibility issues. The web page we create is translated to a java servlet by the server with the help of the web.xml specification present in it.

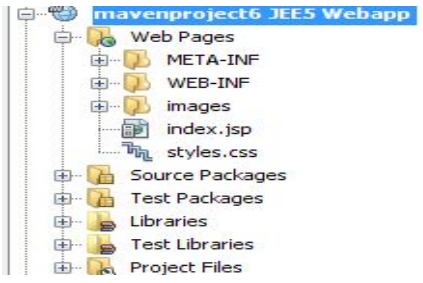

Figure 1: Maven project structure

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The program then needs classes through which it can get connected to the database. Here we have used mysql-java-connector 3.1 library which consists of the com.mysql.connector class. The web application we create here is an Apache Maven application. Apache maven is a tool to manage projects comprehensively. The Maven plugin can be installed for netbeans and the project can be started in it. There are numerous archetypes in maven which describes what scenario the project is made for. Here the maven web application archetype is chosen which will take care of the dependencies by importing the appropriate library to your build path. The project will now contain a source and destination directory and a separate directory for web application where all your scriptlets and server pages can be placed along with the html and css documents.

2. BASIS

The base for creating such an application is the increasing need for better health care facilities. The are many cases in which the patient doesn't actually die due to the illness, but due to untimely and delayed treatment to critical situations. Such situations arise because no one can predict the health condition of an individual and arrive immediately. Moreover a caretaker cannot stay with the patient forever. Only in very rare cases the caretaker stays with the patient but even then, most of the caretakers don't know the nature of the emergency and are not medically trained to suppress the condition. This results in increased risk of fatality due to the disease or serious health deterioration. So we need a system which should continuously monitor the patient, take care of less critical situation, alert the related people in highly critical state and sustain conditions until help arrives. Such a system must be pervasive so that it doesn't need any person to take care of it. We must also make the system as error free as possible because an error in such a self administered system will only be disastrous.

3. SCENARIO

Here we consider an arrangement wherein we have to implement the system in a ward of varying number of patients with different health care need. The system should also be able to house the needs of emergency due to accidents. It should give sustained health care to the admitted patients, keep the doctor fully informed about the patients and alert him when any one is in a very bad condition. We consider each patient having a caretaker who cannot stay in the ward forever but can be near the hospital. Alert conditions must also be specified to the caretaker and prompt him to approach the ward. Each patient is provided a PDA device which is kept besides his bed. Patients have sensors attached which measure their vitals like heart rate (pulse), blood glucose, blood pressure and body temperature. Every bed has a device called UDI which has a provision for adding drugs to it and has a capillary which should be in contact with the patient's blood stream. The hospital has a central server which hosts the web pages and each doctor's room has a computer which is always connected to it. There is a ward manager who notes down the details of all the patients admitted to the ward. This ward manager updates the initial condition and details of the patient in the database for which he is provided a separate application.

4. IMPLEMENTATION

The most important part of this implementation is the database. Construction of a database which houses the essential details of the patient must have various fields which are only sufficient for use. The database is designed with five fields – id, name, age, ailment, status. Here the status field indicates the health condition of the patient. This can be designed with basic SQL queries or we can the GUI options that are provided in the MySQL query browser.

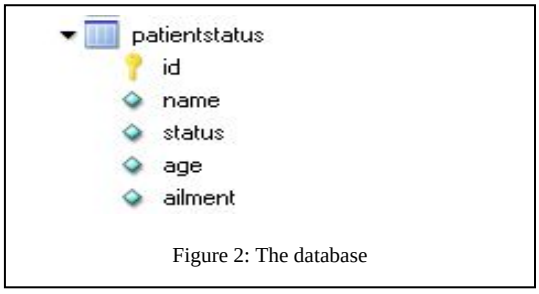

Figure 2: The database

Then design of the ward manager's application comes next. This is a simple java application which has direct connection the database. Hereby the ward anager will enter the details of the newly admitted patients, on the trot.

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```
<terminated> PatientDataInput [Java Application] C:\Program Files\
Enter choice:
1)Enter details
2)view
3)Exit
::
2
1||John Whales||35||normal||cancer
2||Alexander||40||alert||heartattack
3||Sebastian||25||alert||Renal failure
4||Jeoffery||45||normal||accident
Enter choice:
1)Enter details
2)view
3)Exit
::
3
```

Fig: 3 Ward Manger's Application

Whole integration of the dynamic working system has to be planned. We take into consideration the various modules present like the Web applications, the sensors, the PDA middleware and UDI. All the operations necessary are marked for each device.

checks for irregularities in the received sensor inputs. It then controls the UDI by translating requirements to it and also sets the patient's status.

The bundles are then created for the various body sensors required for measuring the vitals of the patient. These bundles are then installed into the knopflerfish framework from where we can start and stop them.

4.1. Doctor's web service

All the Web services associated with this implementation are Remote Procedure Calls. We create an Apache maven application for the Doctor which consists of a POM.xml. This is the Project Object Model which describes the project and what parsing has to be made. First a procedure call is made by the application and the JSP web page

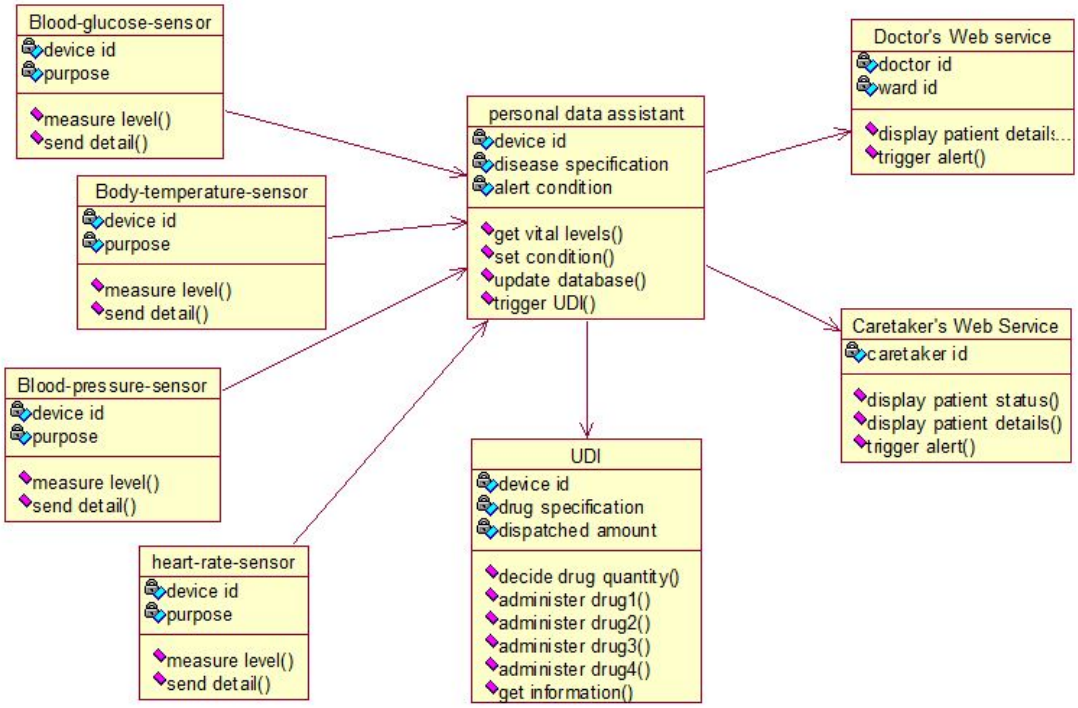

Figure 3: Detailed class diagram of the system

One of the most important aspects of this system is Data translation. The PDA device receives input from various sensors (in this case 4) and processes the information. It actually translates the inputs to the patient's health condition. The doctor predefines the normal and alert level for particular diseases and age groups. Using this information it created by us, is parsed into a java Servlet program which is hosted in the Apache Tomcat server. This has direct connection with the database and updates information every 5 seconds. When the PDA device updates an alert condition, it triggers a procedure which alerts the doctor that the particular patient's status is critical.

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4.2. UDI

Ubiquitous Drug Injector controls the drugs that must be administered for various levels of body vitals. The condition of the patient is conveyed to it by the PDA device after receiving input from the sensors. The chemicals used here are of general purpose. The drug pattern is also scalable with the doctor's redefinition. In some cases a small lapse in special medication provided can be crucial, so such drugs are avoided. For controlling heart rate and blood pressure we use Calcium Channel Blocker (CCB) and Amlodipine. Inulin is used for controlling blood glucose and soluble glucose is used to increase it. Paracetamol is used to control body temperature level. The following image shows the UDI bundle's functionality.

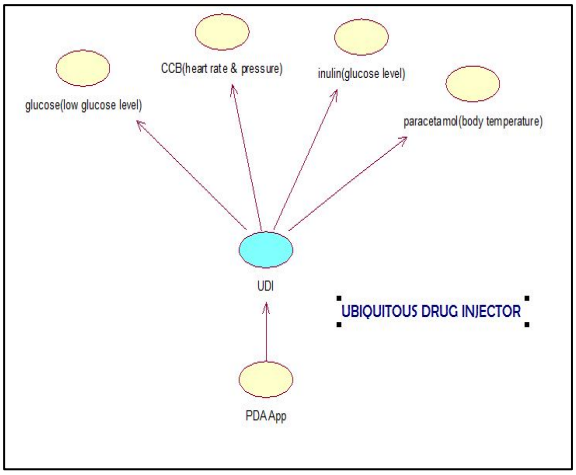

Figure 4: UDI

4.3. Caretaker's web service

The Caretaker's application is very similar to the Doctor's application. The only difference is that, it is different for different caretakers and caters with only the patient they take care of. Once a critical condition is updated by the PDA application of the patient, it triggers the caretaker's application which prompts him to come to the ward immediately.

4.4. Health Metrics

The health metrics differ for each individual. It may vary with the nature of disease and the age of the patient. These values can be specified and stored by the doctor. Both extremes (low and high) of values should be specified by the practitioner for every patient. The dosage of drugs to be administered to the patient also differs for the patients as some may not accustom to certain drugs. These should also be indicated by the doctor to the UDI.

4.5. Alert conditions

The alert conditions are set as mentioned by the doctor for different patients. These can be predefined by the doctor for various ailments and ages so that they are set automatically. These conditions are decided by the PDA application based on the inputs accepted from the sensors. There are only two conditions:

a. Normal – Does not trigger the doctor's or caretaker's web application. Gives the condition to the UDI so that the drugs for health sustenance are administered.
b. Critical – It triggers the applications of the Doctor and the caretaker. It also gives the condition to the UDI so that it controls the situation with the various drugs.

A special condition for abnormal is not necessary here as in normal condition itself drugs are administered by the UDI to sustain health. So a deviation in this case would be due to a more unnatural health condition and needs immediate care.

5. DYNAMIC MODEL

Let us consider a hospital ward with 4 patients. The ward manager initially enters the details of all the four through his application. The ward manager can also view the condition of the patient. But this facility will be on-demand. The sensors are then connected to the patients and the PDA application is started. The application server which is hosted by the hospital is always ready for data entry into the database.

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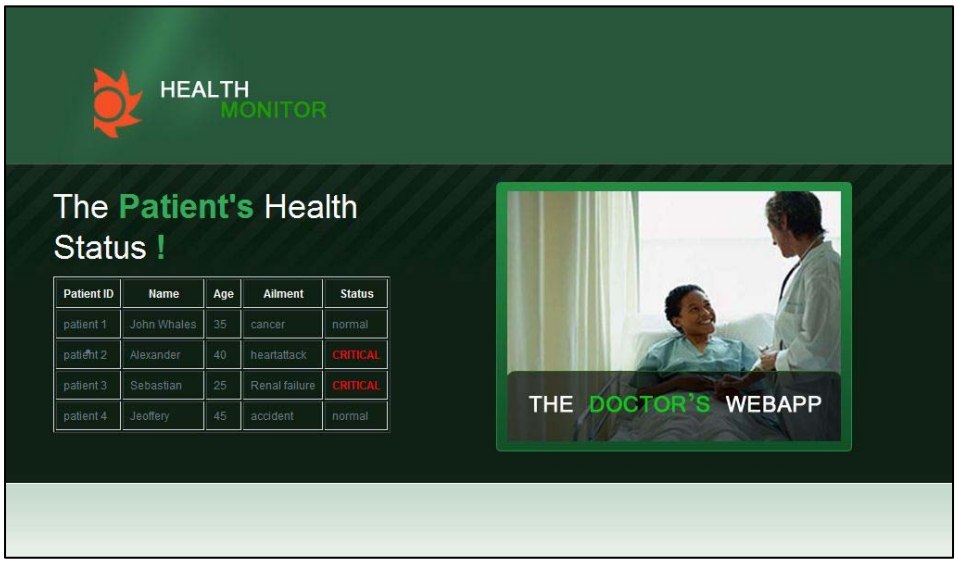
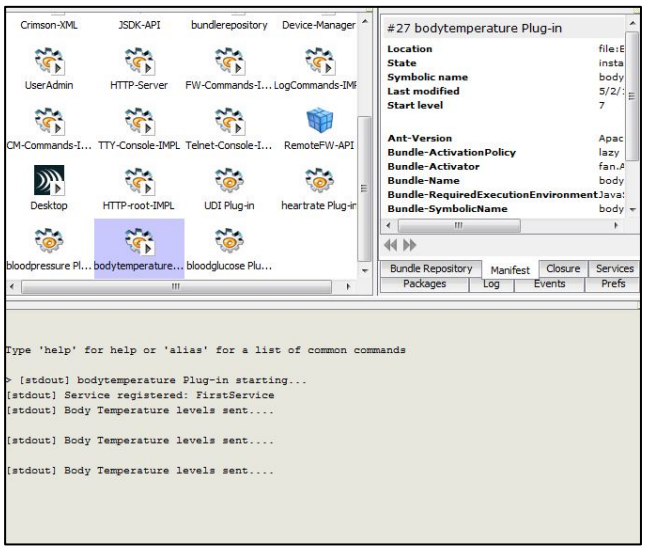


Figure 6: The doctor's web application



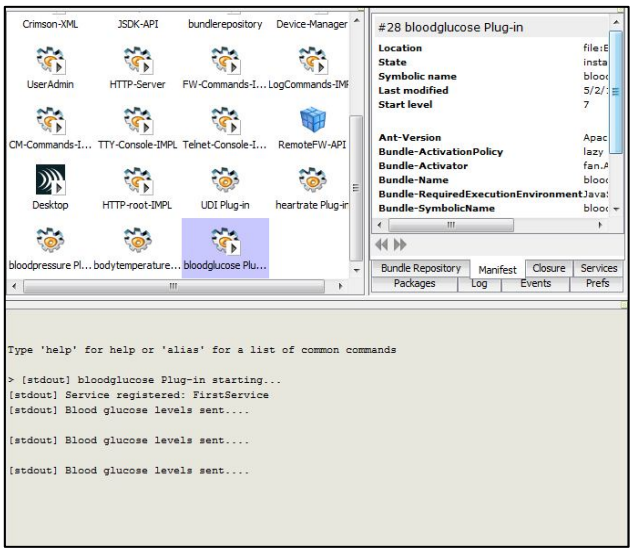


Figure 7&5: Pictures depicting the working of blood pressure and glucose bundles in knopflerfish

Here, for convenience we are considering the conditions of a normal person to check the vitals from the sensors. The optimum blood pressure levels are systolic – 120-140, diastolic 80-95. The optimum heart rate, blood glucose and body temperature levels are 65 – 80, 8 – 10 and 38 – 40 respectively. There are certain conditions like high and low sugar and high body temperature which is not fatal. These are provided special conditions, for which the UDI dispatches drugs which are sufficient enough to suppress the effects of it.

The UDI is connected to the patient who is bed ridden and the device is switched on. The caretaker is then provided his unique id which he can use to access his application and view the status of the patient. With this all the essential components are connected and online.

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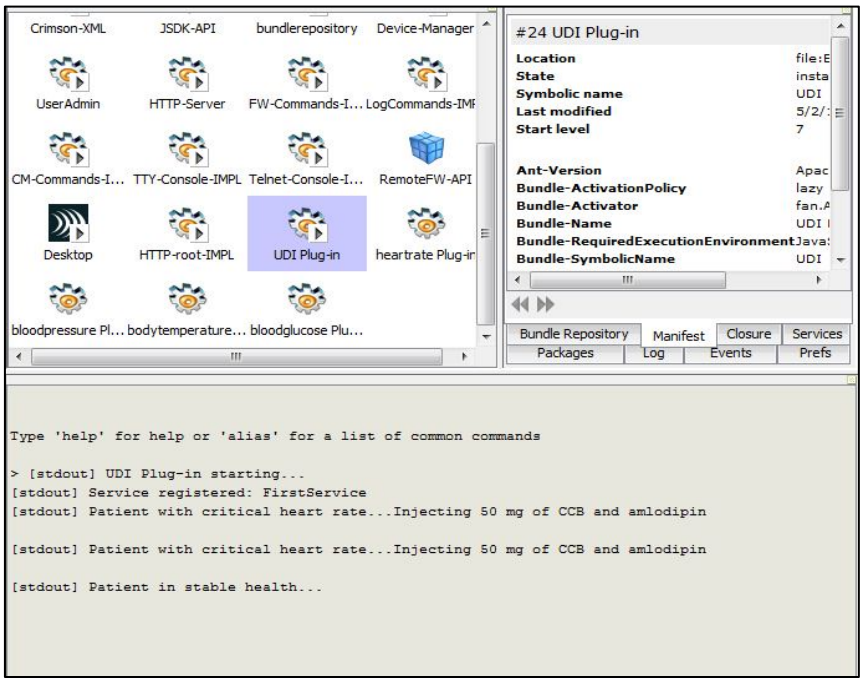

Figure 9: UDI bundle in knopflerfish

Failsafe conditions are defined in the PDA application. These conditions check for values to determine hardware miscue or any lapse in the transmission. This makes the system more reliable and leaves no ambiguity for the Ubiquitous drug injector to administer drugs.

Here we consider the application of patient no 2 i.e. Alexander who is affected by heart attack. His caretaker is updated by the web application which informs him only about Alexander's health condition. The Doctor also knows about his condition along with the others. Once he is intimated of a critical situation he can immediately arrive for treatment as he is informed about the patient a few moments prior to this condition too. When a patient is out of threat and is discharged

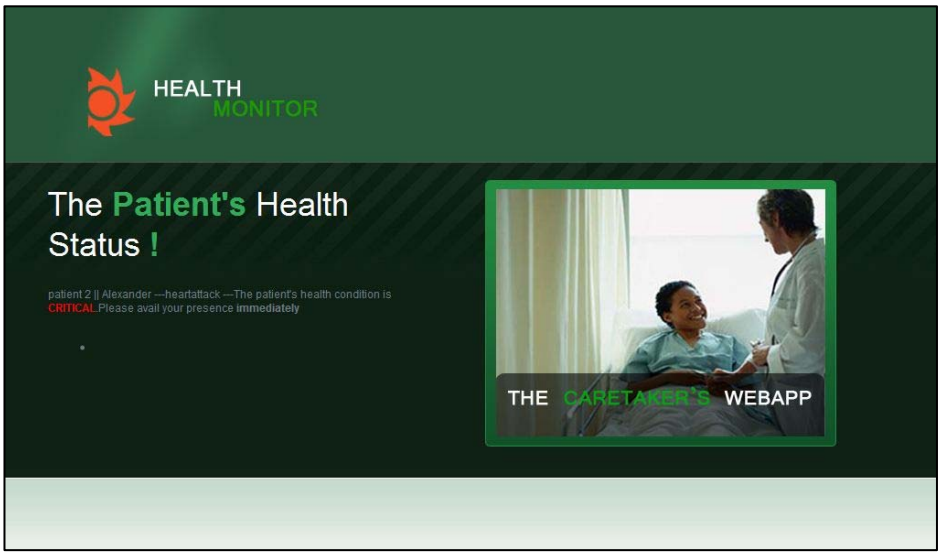

Figure 10: The caretaker's web application

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from the hospital the ward manager removes his entry from the database. When a new patient comes in, he follows the same drill as before. Hence, this makes the system highly scalable and continuous.

6. CONCLUSION

Through our rigorous efforts of attaining a health care system and the various integrations of technologies as mentioned above we have come up with an AAL environment which is highly scalable, efficient, continuous and safe. The application also uses the web to attain information from even remote locations. Such a system is highly needed and appreciated. Still as the saying goes – small droplets of water make up the big ocean, this is just a small droplet in the vast field of health care, and numerous improvements are possible. For instance in the case of accidents the nature of the accident and the part of damage can be noted and the due surgeon can be intimated via the same web triggered method. The Ubiquitous Drug Injector can be profiled to make use of a variety of drugs, this also adds to scalability. Efficient and sustainable healthcare systems add credibility to mankind. Humans may not be blessed with very strong immunity and power like other beasts, but he is blessed with a much more powerful tool called intellect which he can use to create more than just immunity and power. This health care system is a small step on the way to the "Perfect human world" free of diseases and health issues.

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