Pervasive Health Service System: insights on the development of a Grid-based personal health service system

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***Abstract* — Although medical technologies developed in the twenty-first century have successfully increased man's life span, the pressure of modern life has consequently brought many modern civilization diseases and chronic illness. When all these problems are tackled by hospitals, they will consume considerable amount of medical resources. Alternatively, providing health care services at home is an important issue for improving personal health and save hospital resources. In this paper, we present an ongoing project that designs and implements a pervasive health service infrastructure based on the grid system which is integrated with the P2P's resource sharing mechanism, to provide the personal health service. The personal health status is recorded, monitored, and even mined in/from the proposed pervasive health service system for preventive medicine. Additionally, wireless sensor equipments for mobile personal health services are also integrated into the pervasive health service system, in order to construct a situation-aware, context-aware and environment-aware mobile-health-service platform.**

Keywords- health care delivery, medical health information system, high-end technologies

I. INTRODUCTION

The medical technology developed in the twenty-first century has successfully increased man's life span. However, the pressure of modern life and work activities has introduced several of modern civilization diseases and chronic illness; and therefore, large amount of medical resources are consumed. In order to improve the insufficiency of medical resources, also to achieve preventive home care, disease management and health monitoring, new health care systems are upcoming to fulfill these needs. The IT technology is being targeted as the intermediary between the hospital and individual's home. Given that the population in various countries has a phenomenon of aging, providing health-care at home becomes even more important.

In the past, home-care relies only on employing professional-trained nurses, which causes the resource consumption including money and manpower. Hence, many countries have focused recently on the research of home-health-care based on IT technology. Some of home-health-care projects adopt and incorporate the use of mobile devices to monitor patients, as matter for enhancing their pervasiveness.

In this paper, we introduce an ongoing project that proposes the development of a pervasive-health-service system, which is a grid-based personal health service system targeted to fulfill requirements of home-care. It is easy for moderns to suffer from chronic diseases; therefore, effectively using medical resources to help patients through using existing health care system is the purpose of our project. The prototype of the proposed system is being implemented and will be experimentally applied in Taiwan, in order to reduce medical expenses and burdens of the health management from hospital to home. The pervasive-health-service system integrates different medical resources including health apparatus and pharmacy to form an infrastructure in which people could access needed health services for personal health.

In the underlying layer, the grid system integrates with the P2P's resource sharing mechanism to form an infrastructure for supporting personal health services. Based on this infrastructure, the personal health status is recorded, monitored, and even mined in/from the proposed pervasive health service system for preventive medicine. This pervasive health service system supports the capabilities of different resources and data sharing (for instance, personal health data, medical historical records and physician's orders and prescriptions); and these data may be accessed pervasively in the health-care community. In upper layers of this proposed infrastructure, RFID sensors and wireless devices are integrated for supporting mobile personal health services, resulting in a situation-aware, context-aware and environment-aware cyber mobile health-service platform.

The proposed platform supports the abilities of medical information alert, automatic medicine notification,

environment and personal safety warning; therefore, the health-management behavior would be changed. For example, the personal physiology-psychology health service might support the measurement of ECG, body temperature, respiration, and motion posture under convenient and comfortable circumstances. The user's physiological conditions could be monitored at anytime, and users could access health services through an interactive multimedia interface system. The interface of exchanging information between the RFID system and the grid-based system is also being developed for handling daily information in the pervasive-health-care system, with the construction of a huge storage and computing capacity system.

The remainder of this paper is organized as follows. Section 2 presents some related work, while section 3 describes the architecture of the proposed Pervasive-Health-Service Grid system. In section 4, some policies and design issues are introduced and discussed. In section 5, some related applications are presented, and finally, some conclusion remarks are given in section 6.

II. Related Work

There exist a number of researches that focuses on home-health-care systems without considering the grid system underneath. Microsoft has developed a project, named the Microsoft Health Common User Interface (CUI) [22], to provide standardized health services and user interface components. CATV environments were used as an integrated system for home-health-care [9, 11], and patients at home could be attended by doctors who are in the hospital to monitor physician healthcare behavior through CCDs and microphones. When patients are in an emergency state, the home-health-care system could inform the hospital and emergency personnel. Such systems could also support the services of the family medical system.

In the meantime, mobile technologies are also applied to extend the pervasiveness of the system. Physicians in hospitals also can perform healthcare actions via the mobile system. Doctors can get medical data through the system to understand the situation of patients. The system [9, 11] transmits data through CATV; therefore, heterogeneous data travel via different frequencies and power so that they are transmitted in a distributed manner. In this way, doctors easily access patients' current and historical medical data in seconds to achieve real time diagnosis. For instance, patient's information could be shown on the mobile phone through Bluetooth [10], in which the information is sent to the server located in a remote site, e.g., a hospital, by General Packet Radio Service (GPRS). Physicians and patient's families are able to receive patient's health status through the server. Such a system combines GPRS and Bluetooth techniques to enable an environment in which the individual's data are quickly distributed among related doctors and patient's families. Personal medical data and health-care could be stored and archived anyplace, no matter where people physically are located.

Besides, there are some researches about transmitting patients' data via the wireless LAN [5, 7, 15]. These systems can gather the medical data of patients through access points and transmit these data to medical staffs for monitoring. Doctors can more realize the situation of patients via this technology and are able to monitor more patients' health conditions.

Corepoint Health [23] provides solutions to overcome a number of connectivity challenges to multiple remote care locations, by using a web-service-based approach to securely exchange patient information, also develops an interface engine to simplify the complexities of integrating healthcare applications.

At present, the European Union proposes a national e-Health project [18, 19, 20], in which e-Health policies and guidelines are similar to that in our proposed system. The e-Health project integrates medical resources to supply patients with personalized home-health-care. Moreover, they also try to reduce the consumption of medical resources.

III. System Infrastructure

This ongoing project develops a pervasive health service system based on the grid system as the underlying infrastructure. In order to achieve the intelligent health data management, the proposed system utilizes the enormous computing and resource sharing capacities of the grid system to establish a complete health service mechanism.

In order to integrate with the Medicare Grid System [4], an interface in this project enables the translation of common TMT domestic standards with the international standard HL7 [3, 6], through our proposed electronic medical-record format conversion system, which permits electronic medical-records to be interoperable among hospitals and health centers. The integration interface between the Pervasive Healthcare Service Grid and the Medicare Grid adopts the Service Oriented Architecture (SOA) [8, 21] to enhance the system efficiency and interoperability, as well as to provide the grid resource management and related information services [2, 16].

This project also plans to integrate the wearable home-care system [12, 17] as one of top layers in the infrastructure. This proposed system gathers user's physiological signals, such as respiration, body temperature, blood pressure, heart rate, fall detection and others, and monitors the user's behavior and health status. In case of any abnormal situation, the intelligent platform will warn the user and gives some health recommendations [12].

This project consists of two parts: the platform, named the Home Health Grid Platform, and the applications. The "applications" part includes three systems: a) Personal Physical, Mental Health Consultation and Management System, b) Personalized Action Care System, and c) Personalized Physical and Mental Health Service User Interface System. Figure 1 shows the relation among all these parts. The proposed system adopts the grid system as the infrastructure to connect users, families, and hospitals. On top of the grid system, there are a) Personal Physical, Mental Health Consultation and Management System, b) Personalized Action Care System, and c) Personalized Physical and Mental Health Service User Interface System. Users monitor and check the health status through the above listed systems. Additionally, the grid system

connects with the medical grid according to proposed Service-Oriented Architecture (SOA).

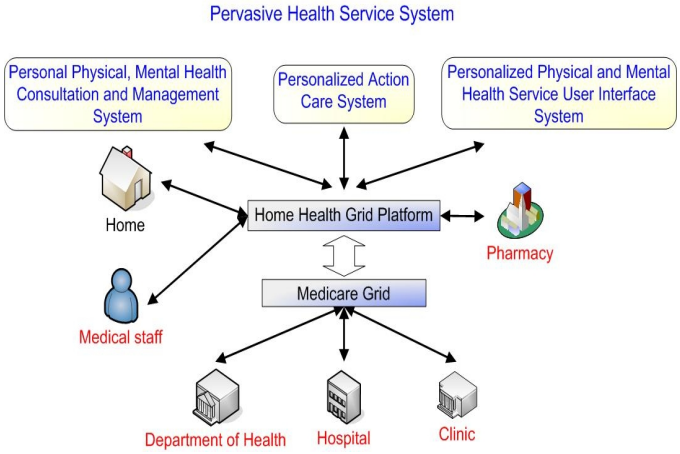

Figure 1. Relationship among Different Services in Pervasive Health System

In order to achieve disease prevention, improve health care quality and lower health care costs, the proposed project refers to the structure of Microsoft Connected Health Framework (CHF) [1] to integrate the four systems, as shown in Figure 2, and this architecture is introduced in Section IV.

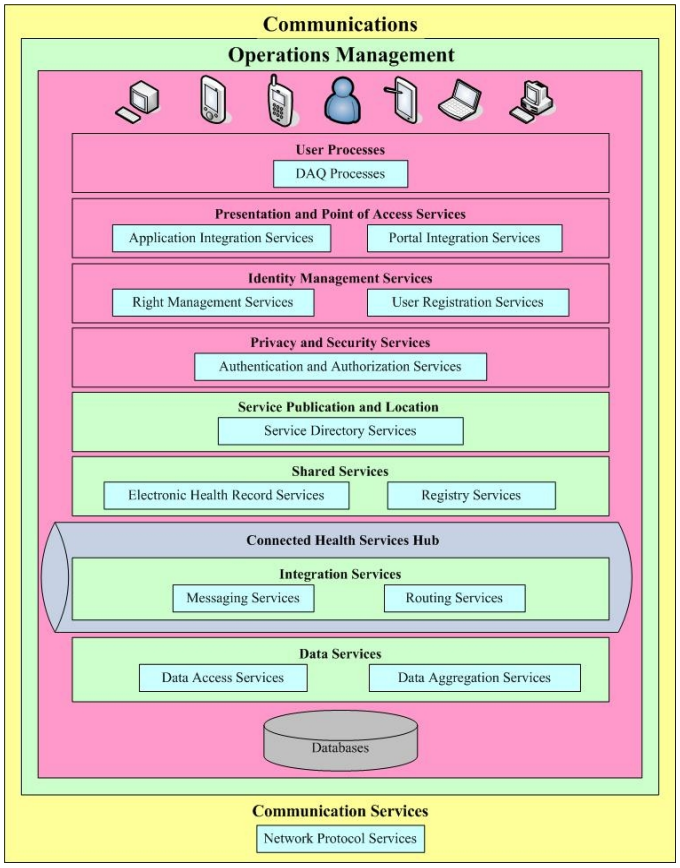

Figure 2. System Architecture

IV. HOME HEALTH GRID PLATFORM

This project refers to the structure of Microsoft Connected Health Framework (CHF) [1] to implement our health service system. According to CHF, our system architecture consists of Communication Services, Connected Health Services Hub, Data Service, Shared Service, Service Publication and Location, Privacy and Security Services, Identity Management Services, Presentation and Point of Access Services, and User Processes. In the following subsections, we will introduce and discuss these services in the proposed system.

A. Communication Services

The Communication Services provide the infrastructure of foundational communication requirements. In this project, we integrate the peer-to-peer and grid technologies to develop our home health grid platform. Based on this platform, we can transmit messages, share documents, and find other home servers or resources.

- Network Protocol Services

Network Protocol Services are provided by the Communication Services based on a number of network standards. In order to improve the performance of the resource search mechanism, we adopt the multi-ring overlay structure based on Chord [13, 14]. This approach solves the problem of the poor ductility of Chord, as also speeds up the performance of resource searching. Figure 3 shows the architecture of a 2-layer multi-ring overlay. Clients are grouped into several groups according to their locations, and those clients belonging to the same group form a Chord ring. In each Chord ring, there is a leader node, and all leader nodes form the upper tier Chord ring.

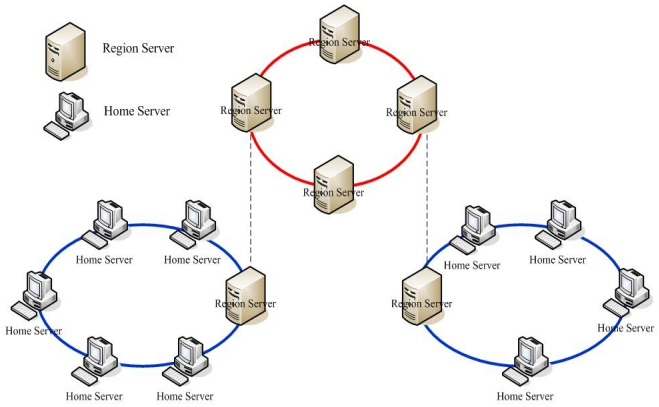

Figure 3. Architecture of Proposed Overlay

In order to prove the efficiency of our proposed overlay, we use the OverSim [24] to simulate the average search time under different numbers of peers in the Chord protocol and in our 2-layer Chord, as shown in Figure 4. From the simulation results, we can observe that the 2-layer Chord method can improve the search efficiency of Chord.

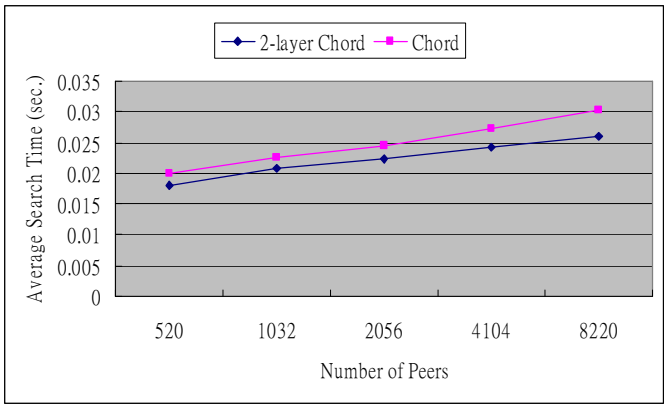

Figure 4. Average Search Time under Different Number of Peers

B. *Connected Health Services Hub*

Connected Health Services Hub connects all services and ensures that the interoperability between them is available. It provides the bridge between network and application protocols, and offers a secure and reliable architecture.

- Messaging Services

Messaging Services adopts the XML (Extensible Markup Language) format for the communication between applications and Web Services. XML is used to represent contents of documents, since it is widely used for the representation of data structures, such as in web services. Therefore, XML is often applied as a message framework for the interoperability between applications and systems.

- Routing Services

Routing Services route messages or documents to the correct destination; that is, messages or documents ought to be routed to the peers that are in the same or different region. We design this service according to our overlay protocol, so that any destination located in other region is reachable.

C. *Data Services*

The Data Services provide a set of data operations, such as data access, data update, and data management. In Data Services, two services are provided:

- Data Access Services

Data Access Services provide standard data access patterns for the health data. These patterns are independent of the database management system.

- Data Aggregation Services

Data Aggregation Services are used for aggregating various health data from different data storages according to a specific defined scheme. These health data may come from home servers, hospitals, or the Department of Health. We can use these services to aggregate our health data.

D. *Shared Service*

In the proposed system, there are a huge amount of health data and health registries needed to be managed, and therefore, the following services are provided.

- Electronic Health Record Service

The Electronic Health Record (EHR) Service is a set of health services that are responsible for capturing, gathering, and summarizing user's health data.

- Registry Services

The Registry Services are responsible for maintaining central health registry indexes which includes patient, healthcare, and location. These services need to persistently keep the health registries' indexing, updating, accessing, and linking.

E. *Service Publication and Location*

As mentioned before, the proposed grid platform is developed based on the service-oriented architecture (SOA). One of the core concepts of SOA is the transparency of the services. When users make use services, they do not need to know where those services are but they still can use those services. In Service Directory Services can achieve this goal.

- Service Directory Services

The Service Directory Services contain all the registered services in the Health Services Hub. This service directory can let users discover the correct services without knowing their physical locations.

Figure 5 depicts the interaction of the service directory. In order to allow users discover and utilize services, the service provider needs to register itself with the service directory. Once this service provider completes the registration process, the service directory knows all details of the service provider. When a service consumer inquires to use a service, he can search for the service by looking for the metadata associated with this service. After finding it, the consumer can direct to its physical address and makes use of this service.

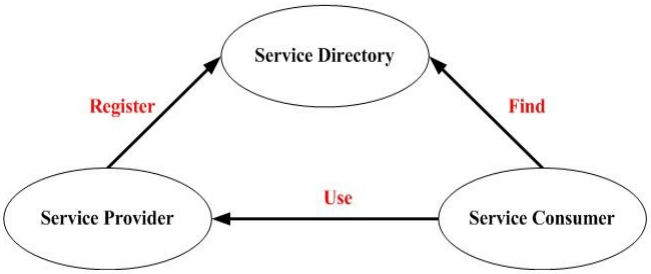

Figure 5. Interaction of Service Directory

The SOA UDDI Register Service is the core component of the SOA architecture in this project. UDDI provides the protocols for a service directory. It allows users to search services' actual addresses through registering services by the Universal Description, Discovery and Integration (UDDI). In our project, we use the Web Service Definition Language (WSDL) to describe the usage of this service and required

parameters. In this way, our services are possible to be deployed in different machines.

F. Privacy and Security Services

Privacy and Security Services handle the system security in the proposed system. Users must have permissions of using various services; and the access data between users must be certified through the security token. Medical data in the proposed system are private; and therefore, we need to consider the data protection and privacy. In our project, home servers may host personally identifiable information that is related to some groups of users. In this way, as a user needs to access medical data, we need to do some authentication in advance.

- Authentication and Authorization Services

The authentication and authorization can be applied to all types of identities. Authentication maps users to a specific identity and differentiates users' credentials. According to users' demand, users can set different authentication levels for security. After the authentication, the identity and authorization are established, so that users can obtain permits for accessing data and services.

G. Identity Management Services

Identity Management Services handle the user's rights and registrations in the proposed system. According to the security token, we can identify different rights for different users.

- Rights Management

In this system, all medical data are private. Each user can decide the access rights and permissions of their medical data. In order to protect users' medical data, users can set different levels of authorization according their will. Different levels of authorization have different rights. For instance, some people who are intimate families can get all medical data but others not. In this way, users can be far from the fear that someone can steal their private medical data resulting in protecting every user's privacy.

- User Registration Services

To ensure the registrations of users are legal is very important. The registration of lots of bogus users can expand the requirement of computational resources and permanently consume storage. In the worst case, these bogus users can cause disruption of the services for legal users. We can make the process of registration more complex and increase the strictness of using services to avoid bogus users.

H. Presentation and Point of Access Services

The system has a friendly GUI. We design the interface based on iGoogle [25] which is developed by Google to make users easier to manipulate the system, as depicted in Figure 6. Users can click and drag widgets to rearrange the layout and meet users' habits. Additionally, users also can delete or add widgets according to their needs. Each widget is one application of our system, and users can easily access these applications through this interface.

- Application Integration Services

Application Integration Services handle the integration of various applications that are provided by our system. These applications have different algorithms and interfaces, so that we use Application Integration Services to integrate them, making them able to work simultaneously.

- Portal Integration Services

Each application has its own user interface, and Portal Integration Services integrate these interfaces to make the user interface is easy to use.

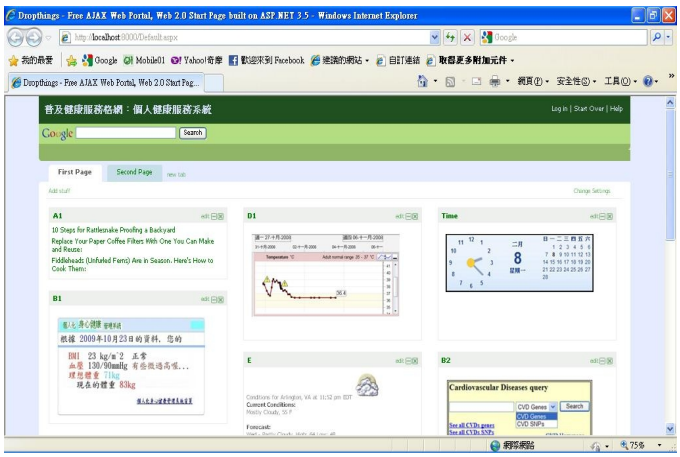

Figure 6. Interface of Proposed System

I. User Processes

In our system, the user process needs to be considered. The influence of user's behaviors should also be considered, and the system must handle the corresponding operations. Through the graphical user interfaces, users could access their health status through a friendly way.

- Data Acquisition Services

Data Acquisition (DAQ) Services can convert analog waveforms into digital values, and may convert health data into the form that we realize. Due to large amount of health data are usually not easy to be analyzed; these data should be converted into some other forms for clear observation and analysis, such as graphical form.

V. APPLICATIONS

In this section, we introduce some applications that are developed and integrated in the proposed health grid platform, as described in following subsections.

A. Personal Physical, Mental Health Consultation and Management System

In order to support home health services, we develop the Personalized Physical, Mental Health Service User Interface System. This system implements the prototype of personalized physical, mental health consultation and management system. By combing with the home health grid platform, we can track and record users' health information at any time to achieve the efficient health data management. From these data, we can analyze them, such as calculating the average number of blood

pressure to know if the blood pressure is too high. We hope to provide a set of health services through the analysis of personal health data to achieve disease prevention and health data management. These health services include the personal health record tracking (attendance records, the follow-up referral / rehabilitation records), disease control, and health consultation systems. According to these health data, doctors can grasp the patients' health problems, give advice or ask patients to the hospital for treatment, so that the scope of services can be broadened to outside hospitals.

Besides, in order to provide the home health consultation and health management based on the health service grid platform, we use data warehousing and data mining techniques to build a cardiovascular disease early warning system. Through personal health data, rehabilitation, dietary record tracking, and the analysis of cardiovascular-related genes, we find out the relevance of implicit information by using data mining. Medical staffs and home caregivers can discover some hidden messages from those associated information and references for health consultation and management.

According to the above concepts, we illustrate the Personalized Physical and Mental Health Service User Interface System in the following two points: home health care data warehouse, and cardiovascular disease early warning system.

1. Home health care data warehouse

For the cardiovascular disease, we design a data warehouse for efficiently recording, managing, and tracking the personalized health management of people who have the cardiovascular disease. Through the analysis of these records and consultations from doctors, the system could help users to prevent the cardiovascular disease and take care of their own health.

2. Cardiovascular disease early warning system

This system uses the genetic information and genome information to provide doctors and patients the risk of cardiovascular disease. The cardiovascular disease early warning system consists of three parts: the analysis of cardiovascular-related genes, the exploration of gene literature, as well as the exploration of protein-protein interaction (PPI). In the future, we will modify the algorithms as well as the mining rules to enhance the accuracy of data mining. In this way, doctors can provide the knowledge to assist the system in clinical practice and the drug reference by this early warning system.

B. Personalized Action Care System

The Personal Action Care System is responsible for integrating the mobile communication mechanisms and the home health grid platform through the RFID technology. We adopt the mobile RFID handheld devices for the personalized action-care, and use the active RFID tags to enable the RFID identification mechanism in daily life. We also develop the data exchange interface between the RFID system and the grid system for data exchange. Due to the requirements of the future service-oriented information and health service industries, this system is committed for the action care systems of an ordinary living environment. The personal action care system includes health information reminding, the notification of prevention and emergency to meet the requirement of personal health care in daily life.

After applying the RFID mobile communication technology to families, outdoors, and public areas, this system also develops a dynamic ZigBee monitor system. The collected data is converted into the XML format and then tag messages are sent to mobile devices via Bluetooth. Therefore, the people within the region could be identified and be tracked the movement path of people or objects through ZigBee components.

C. Personalized Physical and Mental Health Service User Interface System

The Personalized Physical and Mental Health Service User Interface System is built in the home environment and responsible for the interaction with users. The system integrates the wearable sensing technology and the communication interface through an interactive user interface. We use physiological conductive fiber textiles to develop physical information fabric or components, combined with low-voltage, low power consumption of wireless communications. In this way, we develop the personalized exercise physiology wearable sensing platform, so that the temperature, breathing, and other physical parameters can be collected in any time and at any place. We can integrate and analyze this physical information to promote the user's physical and mental health.

In addition to monitor the client's physical status, we also monitor user's daily behavior, such as sports action records, for providing user physical and mental status assessment and health advices. Figure 7 shows the user interfaces of our system for some health statuses of users, such as blood pressure, heartbeat, temperature, and others.

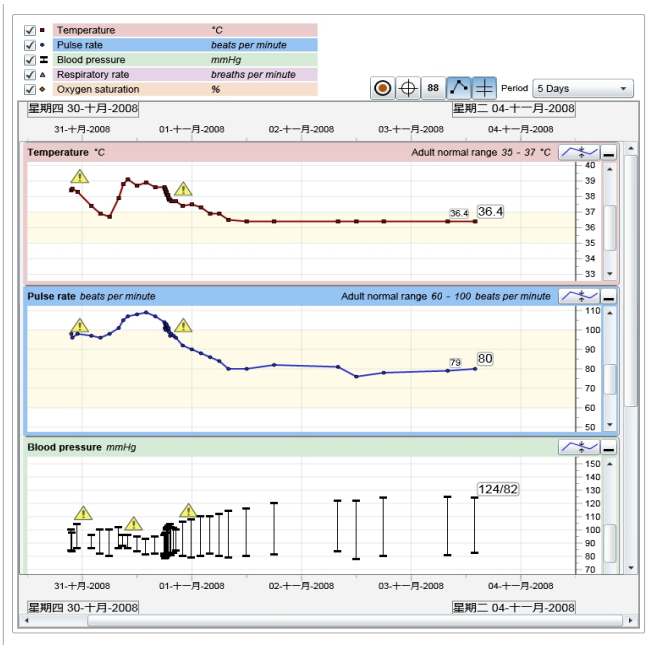

Figure 7. User Interface to Show the Long-term Physical Status

In addition to the general ECG, temperature, respiration, and the movement patterns, we also add the blood pressure, blood sugar, and other physiological signal detection in order to enhance the health service system. We provide more and more messages for the health care workers in order to improve the medical usage. For example, the accurate calculation of the limb's or body's bending angles in exercise, which can contribute to the process of restoration or the tuning of the movement patterns of athletes and supporting also the medical decision-making system for specific diseases.

VI. CONCLUSION REMARKS

In this paper, we have presented an ongoing project that involves the design and construction of a health service grid platform for supporting real-time, automated and personalized information exchanging. A personal, physical, mental health consultation and management system which utilizes selected techniques in data mining to find out the related health information in collected experimental data is proposed, and a complete and personalized module is established after these data are analyzed and mined. Through our pervasive health service system, we can assist hospitals and families to take care of patients with more efficient use of medical resources.

After integrating the mobile communication technology with the wireless communication and location technology based on the RFID, this project develops a mobile health care system with situation awareness and people perception. In the future, our investigation will optimize this health system to provide personalized services and popularization of mobile on-line testing. Our research team expects to make use of these integrated technologies to create a personal home health care system to prevent diseases, improve the quality of health care, and reduce health care costs.

ACKNOWLEDGMENT

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