Development of an Automatic Health Screening System for Reliable and Speedup Measurement of Personal Health Data

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ABSTRACT

This paper describes the detail of an Automatic Health Screening System, which has been designed and implemented with PC connected to campus network, IC card reader and special interfaces for physical measuring devices such as height meter, weight meter, blood pressure monitor and so on. Major characteristics of our screening system are using IC card for user identification, interfacing several kinds of physical measuring devices and transferring measured data with ID-label into the health management database of Health Center in our university. Human errors and incorrect identification can be reduced by means of automatic identification with IC card. Speedup of health screening can be realized through special interface between physical measuring devices and computers. And after accumulating student's health data (a kind of Personal Health Record), efficient retrieval of measured data in such database can be performed with Web-DB system and distributed campuses network environment. With our automatic health screening system, almost students can easily participate in university-level health screening during Routine Physical Examination and reliable measurement of physical/medical data can be also performed in a relatively short period.

KEYWORDS

Health screening, Personal Health Record (PHR), IC card, Interfacing physical measuring devices, Web-DB system for health retrieval.

1 INTRODUCTION

It is very much important for every student of university to receive sufficient Health Education from his or her university. Of course, almost universities want to provide effective Health Education for their students and possibly their staffs. Sometimes, the above universities have prepared to offer trial of their Health Education examples, such as Healthcare consultancy by dedicated doctor(s) and/or Web-based Health consultant services[1]. Although such Healthcare supports and Health Education are very useful and necessary for students as well as staffs, they may not be effective nor expected because students and/or staffs must apply their Routine Physical Examinations. More than medium-scale universities sometimes suffer from lack of environment to provide physical screening in a short period, so that students of the universities have very few opportunities to receive their Routine Physical Examinations in their universities. Because of the above reason, universities need to equip their effective environment of Routine Physical Examination for their students and/or staffs. In Kagawa University, form the same above situation, we have designed and been implemented an e-Healthcare Management Scheme[7] in order to provide an effective Health Education for our students.

In particular, there is very important and necessary to equip some kind of rapid physical screening with automatically-controlled measuring devices which can be interfaced with computers. With such smart measuring devices, it is possible to realize automatic health screening in a short period and reduce human errors and misjudgments in physical screening for a large number of students in universities.

This paper introduces our research background for development of our Automatic Health Screening System in the next(second) section. It illustrates system configuration in detail in the third section. It demonstrates the current state of our system for
the previous Routine Physical Examination in Kagawa University and its qualitative evaluation in the fourth section. It finally summarizes our concluding remarks of this work in the fifth section.

**2 BACKGROUND OF SYSTEM DEVELOPMENT**

This section introduces our research background of system development in order to perform effective health screening at Routine Physical Examination. The first half of the section deals with some related works of our research. And then the second one talks about problems of the past physical examination, particularly, in our university.

**2.1 Related Work**

Omar et.al. discussed an experimental scenario for an e-health monitoring system (EHMS) that uses a service-oriented architecture (SOA) as a model for deploying discovering, integrating, implementing, managing, and invoking e-health services[2]. They said "Such a model can help the healthcare industry to develop cost efficient and dependable healthcare services."

Caceres et.al. said, "E-health is one of the fastest-growing application areas for intelligent mobile services. The ever-growing number and variety of health-related devices and tasks calls for mechanisms to automatically discover, invoke, and coordinate the corresponding services. This, in turn, requires languages and tools that support a semantically rich description of e-health services." Their paper[3] focused on service discovery for medical-emergency management. And it presented a new mechanism for semantic service discovery complements existing approaches by considering relevant parts of the organizational context in which e-health services are used, to improve system usability in emergencies.

Toninelli et.al. said, "Mobile e-health has great potential to extend enterprise hospital services beyond traditional boundaries, but faces many organizational and technological challenges. In pervasive healthcare environments, characterized by user/service mobility, device heterogeneity, and wide deployment scale, a crucial issue is to discover available healthcare services taking into account the dynamic operational and environmental context of patient-healthcare operator interactions. In particular, novel discovery solutions should support interoperability in healthcare service descriptions and ensure security during the discovery process by making services discoverable by authorized users only." Their paper[4] proposed a semantic-based secure discovery framework for mobile healthcare enterprise networks that exploits semantic metadata (profiles and policies) to allow flexible and secure service search/retrieval.

Phunchongharn et.al. said, "Wireless communications technologies can support efficient healthcare services in medical and patient-care environments." By the ways, they pointed out using wireless communications in a healthcare environment to raise two crucial issues:

- The RF transmission can cause electromagnetic interference (EMI) to biomedical devices, which could critically malfunction.
- The different types of electronic health applications require different quality of service.

Their paper[5] introduced an innovative wireless access scheme, called EMI-aware prioritized wireless access, to address these issues. %, namely, the system architecture for the proposed scheme was introduced, and then an EMI-aware handshaking protocol was proposed for e-Health applications in a hospital environment. Their protocol provided safety to the biomedical devices from harmful interference by adapting transmit power of wireless devices based on the EMI constraints.

The paper of De Meo et.al.[6] presented a multiagent system to support patients in search of healthcare services in an e-health scenario. Their proposed system was HL7-aware in that it represented both patient and service information according to the directives of HL7, the information management standard adopted in medical context. Their system built a profile for each patient and used it to detect Healthcare Service Providers delivering e-health services potentially capable of satisfying his needs. In
order to handle this search it could exploit three different algorithms: the first, called PPB, used only information stored in the patient profile; the second, called DS-PPB, considered both information stored in the patient profile and similarities among the e-health services delivered by the involved providers; the third, called AB, relied on A*, a popular search algorithm in Artificial Intelligence.

2.2 Problems of the Past Physical Examination in University

At first of this subsection, we should explain our problems about Routine Physical Examination in the past several years. Health Center of Kagawa University must play the role to provide and manage Routine Physical Examinations at the beginning of April, the first semester of our university because Japanese universities start their first semester in April, while they do their second one in October. All the new faces of the university, every year, have to receive their Routine Physical Examinations just only on the specified day before lectures begin. All the staffs of Health Center have finished the preparation to provide such physical examinations in a short period in order to reduce some accidents and probable mistakes, but they might be sometimes disappointed because of several kinds of human errors and unpreventable troubles.

The flow of Routine Physical Examination is illustrated in the Figure 1. This sample flow shows following three major steps, namely,

1. Using physical measuring devices: An examinee can receive their measured data which are described in paper. For example, in this case, a blood pressure monitoring device shows him/her information about maximal and minimal values of blood pressure and heart pulses per minute, such as 110mmHg, 71mmHg and 81 pulses/min. respectively.

2. Hand writing of data into formatted paper: Staffs of Health Center have to record measured physical data and examinee’s profile into the formatted paper. At the same time, the staffs are required to check whether measured data are suitable or not as well as who is the relevant examinee by means of his/her identification. So it used to become time-consuming and probably human-error-occurred task.

3. Entering data on the paper to computer: Almost thousands sheets of data must be input to computer(s) as fast as possibly, because some examinees want to receive health certificates or medical examination reports which are probably necessary for the job-hunting process. So Health Center must pay out-sourcing cost for such entering data into computer in order to obtain computer-readable data rapidly. At the same time, for such data handling, it must also pay very close attention because relevant data belong to privacy and security domain.

Figure 1. Flow of Physical Examination with Time-consuming Procedures.
These are the reasons to improve the past flow of physical examination described above. It is fact that such a flow are really necessary to have time-consuming and extra-costed procedures. The next section will give some ways to reduce such time-consuming procedures and save probably unneeded out-sourcing cost.

3 SYSTEM CONFIGURATION

This section illustrates system configuration of our automatic health screening system. The section will be separated into the following four subsections, namely, identification of examinee with student IC card for rapid registration of physical examination, software design for interface of Physical Measuring Devices to computers, construction of simple Web-based data monitoring facility for healthcare self-checking, and then future plans of our system expansion in order to generalize system for multiple purpose of Health Management Services.

3.1 Subheadings Identification of Examinee with Student IC Card

Our Kagawa University has employed FeliCa-based IC card for student and staff identification. The detail about FeliCa will be found at the relevant Web information[8]. In our case, such cards have been used for identification of examinee during Routine Physical Examination. Figure 2 illustrates identification of examinee of physical screening with student IC card of Kagawa University. Some profiles about examinee will be read and shown on the computer only when the relevant IC card is placed on the IC card reader connected to the computer, which can be interfaced with dedicated physical measuring device such height meter, weight meter, blood pressure monitor, and so on. This way is a solution to reduce the above complicated task for identification of examinee. And moreover, it is also a solution to remove human errors for hand writing of examinee's profiles and give us a suitable information about examinee to achieve some cross-check. The detail about reading and writing FeliCa-based IC card has been already reported in our previous paper[7] of the international conference of DICTAP2011 held in wonderful Dijon, France. With IC card identification, it has been possible to perform speedup of examinee's identification during several kinds of physical screening as well as avoidance of unneeded human errors which happen when information about examinee is recorded into the formatted paper by means of staffs’ hand writing.

![Figure 2. Identification of Examinee of Physical Screening with IC Card.](image)

3.2 Interfacing of Physical Measuring Devices to Computers

A few years ago, new comers of physical measuring devices have been replaced with according old ones sequentially, which have connectivity to computers by means of USB or RS-232C interface. The former will be easily connected to almost all types of personal computers(PCs), however, the latter is sometimes inconvenient and necessary to equip some kind of
We have prepared such modules for our portable note-PCs in order to connect the relevant physical measuring devices as may be necessary. Especially, note-PCs are sufficient to be used for Routine Physical Examination, because of their portability and manipulation capability.

Figure 3 illustrates an automatic health screening system which is organized with computer, some kinds of physical measuring devices, IC card reader/writer and student IC card. Our automatic health screening system can read not only the relevant data from the target measuring device but also examinee's profile from the IC card reader. It stores(or saves) such data and profile according to the examinee into its temporary storage. Finally, it can write them into network server as well as examinee's IC card as our occasion demands.

The health screening system can select to write data and profile into the specific network-attached information server if it is used in the environment with network connectivity, while it can select to write them into the examinee's IC card tentatively if it is done in another environment without connectivity. In the latter's case, it can utilize FeliCa-based IC card as temporary storage with small capacity. During Routine Physical Examination in gymnastic hall, for example, our screening system must work without network connectivity so that it should manipulate as the following procedures;

1. At first, each examinee applies user identification by attaching his/her IC card on the entrance system. IC card is retrieved and its previous data is stored into backup memory of the entrance system, namely the relevant IC card becomes vacant and available to save the measuring data.

2. During each physical examination, the IC card of each examinee can work as temporary storage and it maintains measured data from each automatic health screening system. Such data are belonging to the relevant examinee, obtained from physical measuring device, and written by the health screening system automatically.

3. At endpoint of physical examination, IC card is checked once again whether all the menus of examination have finished or not by means of reading its measured data by the above entrance system. Such entrance system can play a role to perform the final operation, this time. And finally, all the measured data read by the above system will be transferred into information server.

Of course, our screening system can work in the environment of network connectivity so that it will read examinee's profile from IC card, obtain data from the interfaced measuring device at the same time, combine profile, measured data, timestamp and other attributes into data tuple, access to the target information server, and transfer such tuple into the server as database record for relevant examinee. Such record can be retrieved or browsed through Web-DB monitoring services,
which will be more precisely described in the next subsection.

With our automatic health screening system, the Health Center of Kagawa University can reduce/minimize time-consuming tasks to make up document related to both of measured data and examinee's profile into the formatted paper by means of hand writing. And moreover the Center may not outsource potentially expensive tasks to convert a large amount of data on the formatted papers into machine-readable files.

3.3 Implementation of Simple Web-based Data Monitoring Services

There was another problem how to utilize efficiently the result from our automatic health screening system for Health Education in university. Although our automatic health screening system can more easily take in measured data together with examinee's profile during Routine Physical Examination than past, we have considered such a system to be not so useful for Health Education because the according examination is necessary only a few times, namely once or twice, in the year. So we have thought that our screening system must be applied to more frequently used services.

One of expected services with the result from our health screening system is to realize simple Web-based data monitoring at any place or building in our distributed campus network environment. Doctors as well as nurses of our university may retrieve measured data of the specified student through our secured network service and Web-DB browsing one. They can access the information server which manages all the measured data of the students by means of only pre-registered client PCs and long length-sized passwords.

Figure 4 shows a conceptual image of Web-based data monitoring through campus network as follows;

- A doctor checks some measured data of the specified student on the network environment.
- Such data have been accumulated in the database and classified in a style of time-series clustering.
- They can be manipulated to illustrate how they fluctuate in chronological order.
- Doctors and/or nurses can achieve some kinds of longitudinal data analysis in order to check whether measured data of the relevant student move in on warning/illegal region.

In addition, a more effective service with our screening system is to provide such a system to any student at any time at the satellite office of Health Center in our distributed campus. Namely, any student may be allowed to manipulate an automatic health screening system in order to investigate his/her sampling data for health even if it is not during Routine Physical Examination. The relevant student can recognize his/her parameter(s) of health in chronological order and check by himself/herself whether his/her health is within goodness or not. That is very nice motivation to improve student's health management and pay good attention to health maintenance in university. It is suitable to increase the level of Health Education in our University.
4 QUALITATIVE EVALUATION

This section demonstrates current state and qualitative evaluation of our automatic health screening system.

4.1 Previous Result of Routine Physical Examination

In 2011, we had already applied prototype of our automatic health screening system into some parts of the previous Routine Physical Examination of Kagawa University. Figure5 shows our health screening system for Routine Physical Examination on the table. This system consists of note-PC, IC card reader and Blood Pressure Monitoring device.

![Figure 5. Note-PC connected with IC card reader and Blood Pressure Monitoring device.](image1)

Such system was set on the tables for examinees during our Routine Physical Examination in our Gymnasium just like shown in Figure6.

![Figure 6. Support staffs for blood pressure monitoring.](image2)

And we had equipped some supporting staffs in order not to disturb our measuring at Routine Physical Examination in our Gymnasium by unexpected troubles.

The upper one of Figure7 shows photo of demonstration at the rehearsal for Blood Pressure Monitoring by authors. The lower one of Figure7 also shows displaying measured data on the PC obtained from blood pressure monitoring device.

![Figure 7. Demonstration of rehearsal for blood pressure monitoring test.](image3)

In the practical case of the previous Routine Physical Examination with our system, the below procedures had been performed. Additionally, we had prepared some conditional warning or detection services into our system for the sake of reducing human-error or trouble of man-machine interaction.

- First of all, our system had prospectively-incorporated range(s) of measuring ready to obtain adequate data. This was a useful
mechanism to avoid potential machine troubles.

- Our system had shown the relevant measured data in the categorized form so that each examinee could recognize his/her measured data by visual judgment. And the system could provide warning prompt for examinee if his/her measured data was outside of prospectively-incorporated range(s). For example, at blood pressure measuring, we had set prospectively-incorporated range(s) of blood pressure as follows:

\[
90 < BP_{\text{max}} \leq 140 (mmHg) \\
BP_{\text{min}} \leq 90 (mmHg)
\]

where \( BP_{\text{max}} \) is maximal measured data of blood pressure meter, and \( BP_{\text{min}} \) is minimal one.

- A report about blood pressure monitoring test told us that there was ten times of occurrences to generate warning of mis-measuring for 300 numbers of total examinees. All the above case instructed that the relevant examinees must apply their measuring once again.

It can be considered that these evidences explain certain effectiveness of our system as qualitative evaluation.

### 4.2 Trial utilization of system for pre-Routine Physical Examination

We had recognized that there occurred many problems to be resolved in real application of our health screening system for Routine Physical Examination in 2011. So we decided that our system would be applied for pre-Routine Physical Examination in 2012. Figure 8 shows a photo of environment with our system for pre-Routine Physical Examination in 2012. It is summarized to utilize our health screening system for pre-Routine Physical Examination;

- Preparing a set of our health screening system at the main office of Health Center (at the front desk of office) just shown in Figure 8. Its upper photo shows overall of our system and its lower one focuses blood pressure monitoring subsystem, which is separated into two parts, interfaces for examinee located in the outside of a room of Health Center office and PC connected to Campus LAN located in the inner side of the room.

- Informing students of university that they can receive pre-Routine Physical Examination if and only if they accept some regulations from Health Center (e.g. specified date, number limit per day, etc. for pre-Routine Physical Examination)

- Selecting a set of the relevant students who want to receive pre-Routine Physical Examination at Health Center on the specified date

- Serving the same menu of "normal" Routine Physical Examination for a few number of students who want to receive such an examination before "normal" one.

Figure 7. Photo of environment with our system for pre-Routine Physical Examination in 2012.
4.3 Perspective Problems of Current System

Our automatic health screening system has been depending on the Web-based data monitoring service with regard to data retrieval and modification for the data set of measured data. Of course, the Web-based data monitoring service is another application of our project so we can customize this service to be more flexible and improvable. But there are some difficult problems to be resolved, namely improving user interface, enhancing security/privacy and employing standard methodology.

We will prepare the following three future projects in order to resolve the above problems as follows;

1. Improving user interface: Our prototype version had only simple but fixed user interface for client PCs. It could not satisfy more flexible user client environment[9]. So we were required to develop user interface of Web-based data monitoring for tablet PC, smart phones and so on.

2. Enhancing security and privacy of Web-DB services: Security is very much important and necessary for global access, in particular, outside of university. It would be expensive and time-consuming tasks for us to enhance the current security level up to the reliable usage of our Web-based data monitoring in the external network environment[10]. So we were willing to search collaboration partnership to develop database facility for our data retrieval and modification.

3. Employing standard methodology: Our prototype version was working in the very domestic manner for the demands from Kagawa University, namely it was not global standard. We thought that other universities and/or schools must need health education support system. So we wanted to customize our total system and strategy into more global standard style[11].

We need to design and develop our new system together with our collaboration partner(s) in order to refresh our system with standard methodology.

5 CONCLUSION

This paper describes an Automatic Health Screening System for Student Health Education in Kagawa University. Our health screening system has been applied to the previous Routine Physical Screening Examination partly for staffs of Health Center to avoid human errors and time-consuming tasks related examination. With application of this system during Routine Physical Examination, we can obtain some useful evaluation from trial performance. And such a system can also realize pre-Routine Physical Examination in order to reduce task-loading in the practical Routine Physical Examination and provide more efficient physical screening than before. Characteristics of our system configuration are summarized as follows;

- User identification with student IC card: It is a good idea to employ student IC card for user identification through physical examination. With IC card-based identification, it can be reduced into small amount of time to register and check examinees for physical screening test.

- Interface between measuring devices and computers: In order to build some kinds of interfaces between Physical measuring devices and computers, it must be done to connect device into computer's IO ports such as USB, write dedicated software for interrupts just like drivers and control such devices by computers. With automatic control of measuring devices by computers, we can avoid probabilistically occurred human errors as well as writing mistake of measured data.

- Web-based data monitoring: After obtaining data from physical measuring devices, such data can be accumulated into suitable record of physical screening examination such as e-Health records in database. Such a database will be retrieved by authenticated users through distributed campus information network environment. With some facilities of Web-based data monitoring, it is useful for students to check their periodic state of their own health by themselves.
As result of application of our system to Routine Physical Examination and others, it is confirmed that our system has been qualitatively evaluated to be very useful and effectively for examinees of students and staffs of Health Center.

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8. FeliCa card information provided by SONY: http://www.sony.net/Products/felica/about/index.html