System for Dynamically Sharing Real-Time Biological Signal in Any Place, in Any Device

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Abstract

In the biomedical engineering field, there are an increasing advances into the development of bio-signal sensors that can measure biological signals in routine life. As the development of those technologies begins to accelerate, it became important integrating and sharing the obtained information in real-time. The aim of this study was to develop a system for sharing real-time bio-signal data in any place, and in any device. A prototype web based system, which supports three kinds of biological signals, blood pressure, glucose, and EKG, was developed. A HL7 standard was adopted to solve the problem of transferring the biological signal data from various devices in the distributed areas, and XML technology was used to support the dynamic presentation of information, which is found in various types and formats. This paper discusses this biological signal sharing system in detail. This system can be extended to support other biological signals from any source.

Keywords:
HL7, interface, home monitoring system, XML, SVG, integration

Introduction

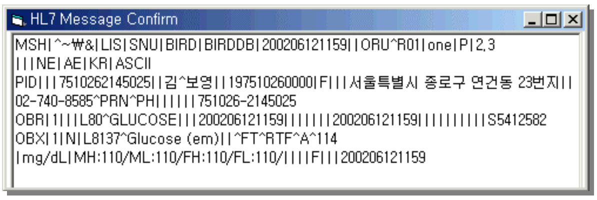
Recently, various types of home monitoring devices have been developed to improve home health care. As the growth of medical information is accelerating, physicians and researchers in the medical field need to be concerned about the integration of the clinical information obtained. Besides various measurements of the vital signs or monitoring devices, it is important to integrate and support the measured data in an efficient home monitoring system [1] [8].

The Medical Record Institute in US reported that 98,000 people in the United States died each year due to medical errors [2]. Medical errors constitute the eighth leading cause of death in the US [3]. A major contributor to this problem is the fragmented and poorly distributed medical information, and the lack of readily available information for the clinicians [4]. Moreover, although an increasing number of devices are used for chronic disease patients at home, there are little signs of improvement in the patient clinical conditions. The main reason for the poor improvement was the lack of coordinated supervision from the medical experts and uneasiness of communication between patients and clinicians.

Therefore, there is a need to collect and arrange data into a clinically easy-to-access format. This study implemented a system that integrates the bio-signal data from distributed sources and dynamically provides the data to the users. This system supports bio-signal data such as the blood pressure, the glucose level, and the EKG that are generated by WebDoc, which is a home monitoring device marketed by ELBIO. There were two big problems in developing a system that dynamically supports the sharing of distributed biological signal data in any place, and in any device. The first is the transferring of data from various sources and the second is supporting a dynamic presentation appropriate for their properties. In order to integrate this information, a standard was adopted for data communication. In addition, in order to support data dynamically, the original data was converted into an XML datagram. This paper discusses this biological signal sharing system in detail. Section 2, provides an overview of the system architecture. Section 3 reviews the HL7 interface gateway, and section 4 discusses a dynamic presentation of biological data on a web based environment. In addition, this paper addresses the implementation results and offers a conclusion and a future direction.

System Overview

The system consists of three parts, a HL7 interface gateway, a biometric integrated repository database (BIRD), and a web server. The HL7 interface is a gateway that transfers data to the central repository. When a home monitoring device measures the bio-signals, the raw data is offered into the HL7 interface gateway, through a RS232C and ASTM X 3.28 protocol. The raw data is converted into a HL7 observation messages and is then transferred to the BIRD. The BIRD is a central integrated data storage. All the data obtained from various home monitoring devices are gathered in this database. We used Oracle 9i for the BIRD database. The web server provides the gathered data to patients and healthcare providers as a web service. This system provides services based on the web to enable access from any device. The raw data is converted into XML document format for various representations. Then XML datagram is published in a dynamic representation that is



```
MSH|^~₩&|LIS|SNU|BIRD|BIRDDB|200206121159||ORU^R01|one|P|2.3
|||NE|AE|KR|ASCII
PID|||7510262145025||김^보영||197510260000|F|||서울특별시 종로구 연건동 23번지||
02-740-8585^PRN^PH|||||751026-2145025
OBR|1|||L80^GLUCOSE|||200206121159||||||200206121159|||||||||S5412582
OBX|1|N|L8137^Glucose (em)||^FT^RTF^A^114
|mg/dL|MH:110/ML:110/FH:110/FL:110/||||F|||200206121159
```

Fig. 1 HL7 ORU message

appropriate for the requested device and converts the data into various formats according to the data type.

Transferring Data from Biometric Device to Central Database

Data Transfer problem

The interface gateway receives the patient monitored data through the RS232C, and the communication protocol is based on the ASTM X 3.28 protocol in order to ensure proper communication. [6] There were two problems to implement this concept. The first was how to transfer the data from the various sources. The second was how to transform the biological signals into a graphical format to be presented dynamically on the web.

In order to integrate this information, two steps need to be done: the first is to adopt a standard for data communication and the second is to develop a versatile device interface for easy connection.

HL7 Gateway Architecture

System Architecture : The overall system consists of a HL7 interface gateway and a biometric integrated repository database (BIRD). The HL7 interface gateway accepts raw data from the various home monitoring devices and converts the raw data into the HL7 observation messages, which is then sent to the central database BIRD.

The interface gateway receives the patient monitored data through the RS232C and the communication protocol is based on the ASTM X 3.28 protocol in order to ensure proper communication. [6]

Development of Gateway

The HL7 interface gateway generates the HL7 messages according to the test results. Because the HL7 triggering event for a home monitoring result is quite simple, only theHL7 observation reporting message type ORU message (Observational report Unsolicited) is adopted. HL7 version 2.3.1 was used because it is used widely at present. The home monitoring device such as a portable EKG or a

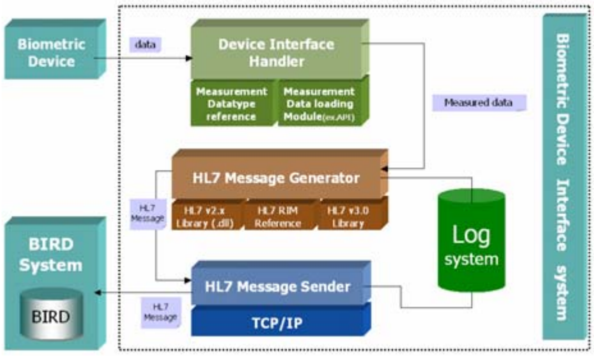


Fig. 2 HL7 Interface Gateway System Architecture

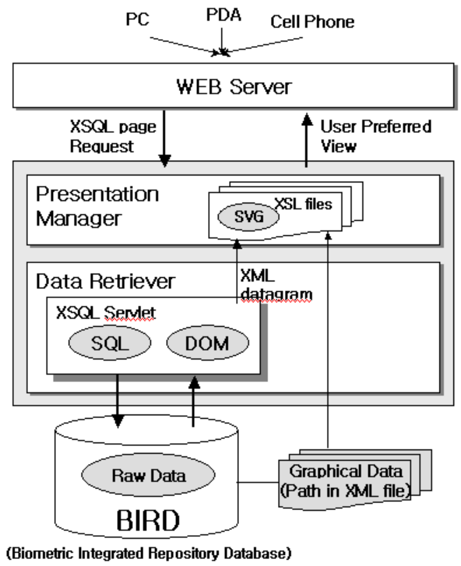


Fig. 3. web server architecture

(a) Raw EKG data

```
100,1 313,9587  100,3 313,7626  100,5 313,5925  100,7 313,2263  100,9 312,4677
101,1 311,4345  101,3 310,8198  101,5 310,6498  101,7 310,7544  101,9 311,0291
102,1 311,5522  102,3 312,3108  102,5 312,9255  102,7 313,2002  102,9 313,2002
103,1 313,3179  103,3 313,2656  103,5 312,6508  103,7 311,8923  103,9 311,3429
104,1 310,8590  104,3 310,1920  104,5 309,4988  104,7 309,0018  104,9 308,5179
105,1 307,9032  105,3 307,6416  105,5 307,9816  105,7 308,4263  105,9 308,8710
```

(b) XML formatted EKG data


```xml
<?xml version="1,0" encoding="UTF-8"?>
<EKG>
    <Window>
        <WindowWidth>1000</WindowWidth>
        <WindowHeight>500</WindowHeight>
        <WindowTopMargin>100</WindowTopMargin>
        <WindowBottomMargin>100</WindowBottomMargin>
        <WindowLeftMargin>100</WindowLeftMargin>
        <WindowRightMargin>100</WindowRightMargin>
    </Window>
    <MaxMin>
        <MaxValue>5</MaxValue>
        <MinValue>-2</MinValue>
    </MaxMin>
    <Paths>
        <Path d=" M100,1 313,9587 L100,3 313,7626 L100,5 313,5925 L100,7
313,2263 L100,9 312,4677 L101,1 311,4345 L101,3 310,8198 L101,5 310,6498 L101,7
310,7544 L101,9 311,0291 L102,1 311,5522 L102,3 312,3108 L102,5 312,9255 L102,7
```


Fig. 4 EKG data. (a) a fragment of the raw EKG data, and (b) an XML formatted EKG data based on the data (a). This document uses a SVG stylesheet to generate the EKG graph.

portable spiro meter measures the patient's data at home and transmits the data to the HL7 interface gateway. The encapsulated data type (ED) is defined for the transport of a large size binary data such as signal data or multimedia date. The OBX segment has the field that can hold the ED type data. (Figure 1).

Figure 2 shows the architecture of the HL7 gateway, which has three main components: the device interface, a HL7 message generator, and a HL7 message sender. The device interface communicates with the biometric devices via a RS232c or a USB channel. The HL7 message generator builds the HL7 messages according to the result reporting event type. The HL7 message sender is designed to communicate the HL7 messages with the BIRD.

The BIRD, which is the central repository, can store the clinical and health data in chronological order. A webserver built over the BIRD will reply to the user query via a web interface. XML technology was also adopted for the communication of multi platform devices, as it is able to convert document data in the user predefined device format [5] [7].

Dynamic Presentation of Biological Signals

Web Server Architecture

The architecture of the web server is shown in figure3. In order to support the presentation on multi-platform devices including a desktop PC, PDA, the raw data is converted into the XML format using Oracle XML technology, XSQL. XSQL combines the power of XML and SQL to provide a language and database with independent means of storing and retrieving SQL queries and their results [9] [10]. When a user device requests information from the web server, the XSQL Servlet queries the requested information to the central database, the BIRD. It directly maps the retrieved data into XML tags. The resulting XML data is then transformed into html format according to the associated XSL file.

Using this web-based system, any desktop or even handheld devices can access the BIRD database. Moreover, although toe data was converted only into html format, it can be easily extended to generate other formats such as WML by simply adding the XSL files that lists the transformation codes for that kind of result document type. Therefore, this system can support data for any devices.

The biological signal data can be viewed as its properties and user preferences. For example, numeric data such as the blood pressure and glucose values are represented as tables(figure 6(b)). However, the EKG data or accumulated blood pressure and glucose data are represented as graphs.

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.0//EN"
 "http://www.w3.org/TR/2001/REC-SVG-20010904/DTD/SVG10.dtd">
<svg width="1000" height="500" preserveAspectRatio="xMidYMid meet"
xmlns:xmlns="http://www.w3.org/2000/svg" zoomAndPan="magnify">
<rect x="100" y="90" width="800" height="310" style="fill:white"/>
<line x1="100" y1="90" x2="100" y2="400" style="stroke:black; stroke-width:0.5"/>
<line x1="900" y1="90" x2="900" y2="400" style="stroke:black; stroke-width:0.5"/>
<line x1="100" y1="90" x2="900" y2="90" style="stroke:black; stroke-width:0.5"/>
<line x1="100" y1="400" x2="900" y2="400" style="stroke:black; stroke-width:0.5"/>
<g>
<text x="80" y="102" style="align:center" startOffset="0">5</text>
<text x="80" y="145" style="align:center" startOffset="0">4</text>
<line x1="100" y1="143" x2="900" y2="143" style="stroke:e6ffff; stroke-width:0.1"/>
<line x1="100" y1="143" x2="110" y2="143" style="stroke:black; stroke-width:0.5"/>
<line x1="890" y1="143" x2="900" y2="143" style="stroke:black; stroke-width:0.5"/>
<text x="80" y="188" style="align:center" startOffset="0">3</text>
<line x1="100" y1="186" x2="900" y2="186" style="stroke:e6ffff; stroke-width:0.1"/>
<line x1="100" y1="186" x2="110" y2="186" style="stroke:black; stroke-width:0.5"/>
<line x1="890" y1="186" x2="900" y2="186" style="stroke:black; stroke-width:0.5"/>
<text x="80" y="231" style="align:center" startOffset="0">2</text>
```

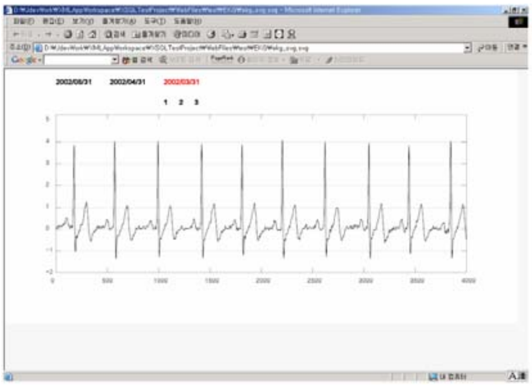
Fig. 5. html source code containing the transformed EKG SVG graphs

There are several problems in presenting data in graphical way. Unlike a table format, there is no specification for graphical representation in html document. It only shows link images which are pre-stored images. Therefore, the original data should first be transformed to a graphic image and then stored it in some repository. This solution has several limitations. Graphical data cannot be generated dynamically. In addition, this requires a large amount of storage. As a solution of this problem, SVG(Scalable Vector Graphics) 1.0 specification was implemented to dynamically generate a graphical result from the raw data.

Presentation of biological data in graphical form

1) *SVG(Scalable Vector Graphics):* SVG is a W3C Recommended language for describing two-dimensional vector and mixed vector/raster graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes (e.g. paths consisting of straight lines and curves), images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. [11] [12].

2) Graph generation process : the HL7 interface module over the BIRD converts the raw EKG data in a HL7 message into an XML document and only its file name is stored into the BIRD. The transformed XML document contains the graphical configuration information such as the window size, the maximum and minimum value of the graph, as well as the path information. The path consists of coordinates and graphical instructions (e.g. M is the moving point, and L is the lining from the previews point to point). This XML formatted document is for dynamically creating an SVG image. An example of the raw data as well as the transformed XML data is shown in figure4.



(a) EKG graph dynamically published on a web page

계측일시	Blood pressure(min)(mmHg)	Blood pressure(max)(mmHg)
2002/04/03	137	132
2002/04/02	127	122
2002/04/01	117	112
2002/03/30	109	117
2002/03/28	112	120
2002/03/27	102	110

(b) blood pressure values represented in table

fig. 6. the representation results of the biological signal data

Generally, EKG applications only provides the data in wave format. Therefore, in this application, additional XML format data was stored to reduce the XML datagram generation time. In addition, this does not use up a large amount of storage space compared to the space required to store the image data.

When there is a request for an ECG graph, the XSQL page retrieves the ECG XML documents. When the data link is clicked on, the SVG stylesheet directly(dynamically) converts the ECG XML data into a graph format and the graph is displayed to the user.

Other data such as the accumulated blood pressure values or the glucose values is shown to the user in a similar way.(This system does not store other XML formatted data for two cases because it has small amount of data values.)

There are several advantages in transforming the raw data with an SVG stylesheet. Multiple ECG graphs can be loaded at once and the requested data can be shown dynamically. An enlarging view for the focused area is also available because the SVG provides the vector graph. In addition, the raw data value can be observed in the source html (figure5).

Result

The prototype system worked well on a web. All the data generated from WebDoc was successfully transferred to our central system with the HL7 messages. In addition, the gathered data was transformed in html format with the XSLT processor. In the first stage development, only the web browser for desktop PCs is supported. However, it is can easily be extended for mobile devices by simply designing the XSL files for those devices. EKG raw data was converted into XML document format and SVG was used to transform an EKG XML datagram into EKG graph format. By using SVG, a real-time EKG graph could be could successfully provided on the web(figure 6(a)). The user requested range of EKG data could be loaded at once in a page, which showed it as an animated view. Furthermore, since the graph is a vector graph that is generated dynamically based on the raw signal values, the graph could be magnified or reduced without breaking the original graph format. The accumulated blood pressure and glucose values were also able to published in graphical format that was similar to the EKG data case.

Conclusions and Future Work

A system that dynamically shares biological signal data in any place, and on any device was developed in this study. HL7 was used for data transfer among the devices as well as the BIRD central database. In addition, the gathered data was retrieved as an XML format and published through the XSLT processor. The numeric EKG data, the accumulated blood pressure and glucose values were transformed in graphical format with the SVG stylesheet. By using SVG stylesheet, we could provide the real-time information as flexible and dynamic graphical format. With this system, the data could be shared between any of the distributed WebDoc monitoring devices. Furthermore, an access device specific view that fully supports the three test set of biological data could be generated.

This system architecture can be extended to other biometric devices. However, there are still some problems left. The main problem is the system compatibility with various source devices. Investigations aimed at providing a versatile device interface for an easy connection are currently underway.

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