An U-Healthcare Implementation for Diabetes Patient based on Context Awareness

Jeong-Won Kim, *Member, KIMICS*

Abstract—With ubiquitous computing aid, it can improve human being's life quality if all people have more convenient medical service under pervasive computing environment. In this paper, for a pervasive health care application for diabetes patient, we've implemented a health care system, which is composed of three parts. Various sensors monitor both outer and inner environment of human such as temperature, blood pressure, pulse, and glycemic index, etc. These sensors form zigbee-based sensor network. And as a backend, medical information server accumulates sensing data and performs back-end processing. To simply transfer these sensing values to a medical team may be a low level's medical service. So, we've designed a model with context awareness for more improved medical service which is based on ART(adaptive resonance theory) neural network. Our experiments show that a proposed healthcare system can provide improved medical service because it can recognize current context of patient more concretely.

Index Terms—ubiquitous, ART(Adaptive resonance Theory), sensor network, healthcare, etc.

I. INTRODUCTION

Ubiquitous computing is the most upcoming technology in IT industry on 21th century. To realize this technology, it needs various technological elements such as network, application, platform and device standardization. Also, access conveniency, security problems have to be solved in advance [1, 2].

Healthcare service in ubiquitous application may improve human beings' life quality and current service is just limited on some simple service such as heart pressure, electrocardiogram, etc. But if the element technologies are solved, more improved healthcare service may be introduced.

For life care service, blood component detection sensor, environment monitoring sensor, body signal analysis, activity tracing technologies are lively studied with IT combined[3,4,5,6].

Also, in other applications, an organism detection service can notify doctor urgent messages of heartbeat and oxygen saturation electrocardiogram through sensor network and old people care service can monitor their health with badges attached on their clothes[7].

Ubiquitous sensor network on pervasive environment means a wired or wireless telecommunication technology based network which is formed between sensor nodes to utilize both environmental and physical information for human life. The basic operation process is as follows:

Sensor node transfers data which is service request or created information to sink node, which responds to user actions or uses the data statistically.

This sensor node means a system that transfers the initial data monitored in physical world through a wired or wireless telecommunication technology. This node is composed of processor which performs data processing, communication channel establishment, middleware processing. The sink node is called base node or relay node because it communicates with outside network without IP.

In this paper, we have implemented a healthcare system that can monitor diabetes patient based on the previous research [8]. The implemented prototype is composed of two parts: front-end and back-end. The front-end monitors' patient's body signal and transfer these data to gateway through a sensor network. The back-end stores body signals, analogizes the data, and then automatically sends message to doctor if any urgency.

These sensor nodes is very small one which TinyOS[9] is installed, operates zigbee, and forms sensor network with other nodes. Theses main actions are to collect body signal, process adequate format and transfer these data to server. And gateway is mobile terminal which functions a connection between sensor network and outside network.

The previous works related with our paper focus on

Manuscript received July 3, 2009 ; revised September 1, 2009

Jeong-Won Kim is with the Department of Computer Information & Engineering, Silla University, Pusan, 617-735, Korea (Tel: +82-51-999-5749, Fax: +82-51-999-5657, Email: jwkim @silla.ac.kr)

monitoring human body and doing adequate action as well as observing environment of human beings. But, to provide an improved health service, whether the patient is good, bad or trivial state should be considered. Then context recognition technology must be used in the healthcare system.

This paper is composed as follows: chapter 2 shows related works, chapter 3 depicts the implemented prototype, chapter 4 suggests a context recognition model, chapter 5 shows experiment results, and chapter 6 draws a conclusion.

II. RELATED WORKS

Generally, healthcare system needs variable technologies such as human body sensing, sensor network, middleware. This chapter introduces these related works.

Elite care [10] adopts various ubiquitous technologies and monitors real life health of old people who are attached location trace sensors to theirs body. These bed sensors check weight and movement. Sensors in restroom check electrocardiogram and body temperature. Sensors of toilet stool can measure glycemic index. Locestor's smart mirror can check skin variation. Its belt measures glycemic index and its smart socks electrocardiograms [11, 12].

Projects to establish ubiquitous network are as follows: CoolTown[13], Aura[14], Pervasive computing, Smart Its[15], EasyLiving[16], TTT[17]. HP's CoolTown project connects between real world and cyber world and it is composed of World Wide Web, software, service, and facilities. CMU's Aure project is about invisible computing and its basic idea about the most important computing resource is human concentration as hardware source is already enough developed.

Pervasive computing is to locate computer and sensors in every place such as device, house, office, factory, etc. Microsoft's EasyLiving project is to create an intelligent space so that everyone can live conveniently. The TTT of MIT media lab is that computer comes to human's daily life, cooperates with each other and can help human's life. To realize this idea, various intelligent technologies are used.

Now, works about context recognition are introduced. [17] provides a model to conduct standing, walking, sitting using wearable acceleration, angular velocity sensor. [18] is house_n project of MIT and provides context recognition model to recognize old people's daily life. [19] disposes microphone, record all sound, and recognize context to percept all activities of human in house. [20] provided a model to cognize hospital works' activities who attaches RFID tag in their body. It creates special induction rule and updates the rules through works' experience, but handling these rules may be too difficult to general workers. [21] uses backpropagation neural network to monitor hospital workers' activities who use PDA. It monitors daily activity of workers but this paper can cope with only urgent context of old people.

III. AN IMPLEMENTED U-HEALTHCARE PROTOTYPE

This chapter describes the structure of implemented healthcare system to recognize the context of diabetes patient.

Figure 1 is an implemented prototype in which user always attaches sensor in one's body and one's physical state is automatically monitored, which continuously transferred to medical information server.

Our prototype is composed of two parts: frontend and backend. Sensors in frontend construct a sensor network through zigbee and base sensor node collects all sensor data and transfers these data to gateway. Also, the gateway is a kind of mobile Linux terminal which delays sensor data to backend.

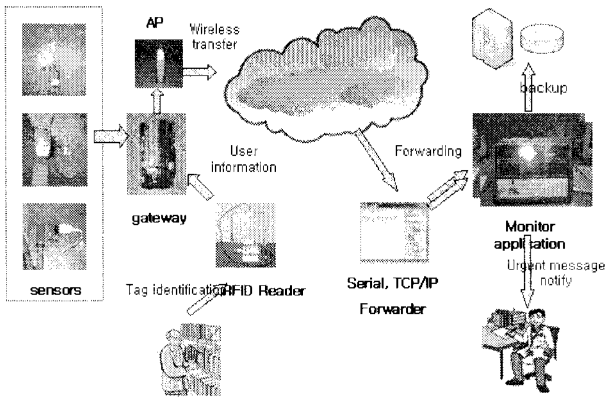


Fig. 1 System structure

A medical information server in backend is constructed and accumulates the patient's body state. And, through backpropagation neural network, it recognizes the patient's context and provides doctor provide more improved medical service.

A. sensor node

Our implementation has installed the tinyOS of Berkeley university and telos[9,22] platform for sensor node. This telos platform is based on TIMSP430 microcontroller and Chipcon2420 RF-installed sensor which is featured low power consumption as well as zigbee protocol support. The version of TinyOS is 2.x and all applications were developed by NesC.

A device of Genecell Company can measure blood pressure, pulse, and glycemic index, which is attached on wrist and can easily check them. We have developed a sensor node attached to this device which gets sensed data and transfer to base node.

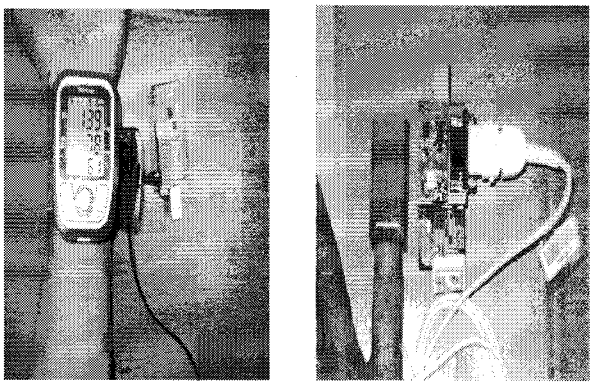


Fig. 2 Blood pressure(left) and diabetes sensor node (right)

1) Protocol

This blood device of Genekcell Company supports RS-232C with 9600 bps and also transfers sampled data to PC with Cp2101 USB to UART Bridge of Silicon Laboratories.

First 1bit is start bit with value 0, middle 8 bits is data and first sends LSB, and last bit is stop bit with value 0. This device outputs total 11 bits and main features is as follows: Rxd / Txd Send triple wire, Data 8 bit x 1 stop bit, parity bit none, start bit 1.

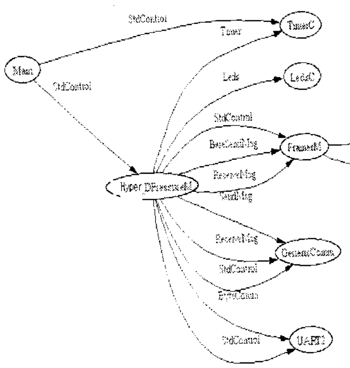


Fig. 3 Event diagram

2) Event diagram

Figure 3 is a event diagram of this sensor node. Since the NesC is event driven language, the operation feature is characterized by event diagram. In this figure, the Hyper_DPressureM component is connected timer, LED, UART1, UART2, GenericComm, and FrameM. The timer is to sample blood related value periodically. LED is check communication status as well as debugs a sensor node. And GenericComm is to transfer sensed data by RF or serial port to sensor node. FrameM component is connected to Hyper_DPressureM to transfer sensed data to base node.

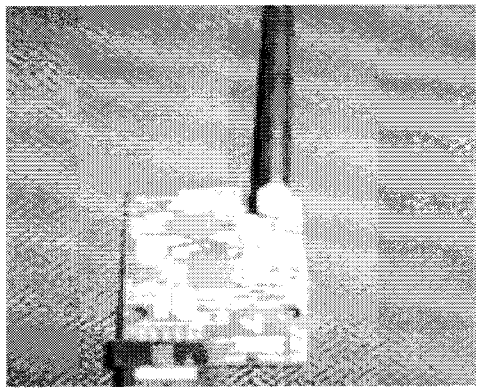


Fig. 4 Base node

B. Base node

This base node collects data generated by sensor node and transfers these sample data to gateway. The base node communicates with sensor nodes by zigbee and figure 4 is base node.

MCU of base node is Atmega128L and Chipcon's CC2420 is used for node's RF. Some ports are used for downloading and debugging and attached to gateway. Our base node is composed four parts: power supply, RF, MCU board, serial interface for gateway connections. 750mAh*2 battery or gateway's power is used for base node power. RF part is composed of Chipcon CC2420, 16MHz crystal and SMA connector to attach 2.4GHz antenna.

C. Gateway

As the data generated by base node is needed to send to a wired or wireless server, we have implemented a moble device installed embedded linux.

Since CPU of the gateway is intel PXA270 Bulverde with clock speed 520MHz, it can display multimedia data of medical information. Flash memory has 64MB capacity enough to hold bootloader, kernel, root file system, and user file system. Main memory's capacity is 128MB and it can display multimedia data. LCD is 3.5 inch size and has 2 ethernet ports, PCMCIA, serial, bluetooth interface. Secondary storage of gateway can support CF. Our prototype uses HDD since the HDD is more cheap than CF. We've implemented low price mobile terminal with HDD. Keypad and touch screen is used for input interface.

D. Healthcare server

Figure 5 is a healthcare monitor application to display user's status. It can monitor current status of patient with user or service provider connected by wired or wireless communication.

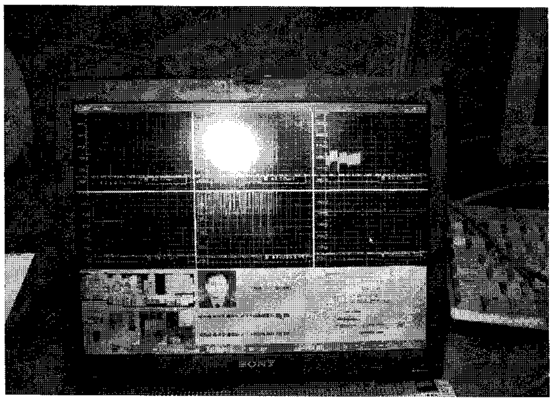


Fig. 5 Monitor applicaiton

This application was developed with java language, supports bi-directional input and output of various information coupled with database server, and connected to doctors.

The sensing graph shows sensing value of various sensor nodes in realtime such as temperature, humidity, brightness, sound, pulse, blood pressure, and glycemic index. The displayed values automatically stored in database.

The indoor structure is used for rapid context recognition of the patient by healthcare provider who can deal with urgent status, find patient easily, and find out the installed sensor node location.

The private information panel displays picture, name, address, phone number, etc. This information is displayed through RFID tag of the patient. And graph control panel adjusts graphic display of all panels and have the following function: zoom, save, load, hex value display, and scroll.

Ⅳ. ART-BASED CONTEXT AWARENESS MODEL

We think that simple delivery of sensing data to medical team is lower level of u-Healthcare. So, in this work, we introduce ART neural network model to sophistically judge patient context. The ART is for the categorization of patterns using competitive learning paradigm. It introduces a gain control and a reset to make certain that learned categories are retained even while new categories are learned. It is successful in addressing the plasticity-stability dilemma[23].

ART makes much use of a competitive learning paradigm. A criterion is developed to facilitate the occurrence of winner-take-all phenomenon. A Single node with the largest value for the set criterion is declared the winner within its layer, and it is said to classify a pattern class. So, ART-1 network is useful to build up autonomous learning system. This network automatically divides input patterns and can recall the past patterns. If a new pattern does not match any past patterns, this network recognizes it new category.

We use ART1 model in this context awareness [23]. We follow the description of the algorithm found in James A. Freeman and David M. Skapura[24]. The following equations, taken in the order given, describe the steps in the algorithm. Table 1 is notations for ART1 calculations.

Table 1. Notations for ART1 calculations

symbol	Description
w_{ij}	Weight on the connection from the ith neuron in the F_1 layer to the jth neuron in the F_2 layer
v_{ji}	Weight on the connection from the jth neuron in the F_2 layer to the ith neuron in the F_1 layer
a_i	Activation of ith neuron in the F_1 layer
b_j	Activation of jth neuron in the F_2 layer
x_i	Output of ith neuron in the F_1 layer
y_j	Output of jth neuron in the F_2 layer
z_i	Input to ith neuron in F_1 layer from F_2 layer
δ	Vigilance parameter, positive and no greater than 1
m	Number of neurons in the F_1 layer
n	Number of neurons in the F_2 layer
I	Input vector
S_i	Sum of the components of the input vector
Sx	Sum of the outputs of neurons in the F_1 layer
A,C,D	Parameters with positive values or zero
L	Parameters with value greater than 1
B	Parameter with value less than D+1 but at least as large as either D or 1
r	Index of winner of competition in the F_2 layer

F_1 layer calculations:
$A_i = I_j / (1 + A (I_i + B) + C)$
$X_i = 1$ if $a_i > 0$, 0 if $a_i \leq 0$

F_2 layer calculations:
$B_j = \sum w_{ij}\, x_i$, the summation being on I from 1 to m
$Y_j = 1$ if j_{th} neuron has the largest activation value in the F_2 layer
0 if j_{th} neuron is not the winner in F_2 layer

Top-down inputs:
$Z_i = \sum v_{ji} y_j$, the summation being on j from 1 to n
F_l layer calculations:
$A_i = I_j / (1 + D z_i - B) / (1 + A (I_i + D z_i) + C)$
$X_i = 1$ if $a_i > 0$, 0 if $a_i <= 0$

Checking with vigilance parameter:
If $(S_x / S_i) < \delta$, set $y_j = 0$ for all j

Modifying top-down and bottom-up connection weight for winner r:
$V_{ir} = (L / (S_x + L - 1)$ if $x_i = 1$
0 if $x_i = 0$
$W_{ri} = 1$ if $x_i = 1$
0 if $x_i = 0$
w_{ij} should be positive and less than $L / (m - 1 + L)$
v_{ji} should be greater than $(B - 1) / D$
$a_i = -B / (1 + C)$

All the variables are defined in the Table 1. Having finished with the current input pattern, we repeat these steps with a new input pattern. We lose the index r given to one neuron as a winner and treat all neurons in the F2 layer with their original indices.

The above presentation of the algorithm is hoped to make all the steps as clear as possible. The process is rather involved. To recapitulate, first an input vector is presented to the F1 layer neurons, their activations are determined, and then the threshold function is used. The outputs of the F1 layer neurons constitute the inputs to the F2 layer neurons, form which a winner is designated on the basis of the largest activation. The winner only is allowed to be active, meaning that the output is 1 for the winner and 0 for all the rest. The equations implicitly incorporate the use of the 2/3 rule and they also incorporate the way the gain control is used. The gain control is designed to have a value 1 in the phase of determining the activations of the neurons in the F2 layer and 0 if either there is no input vector or output from the F2 layer is backpropagated to the F1 layer.

Table 2. An example of training pattern

Time	blood pressure	pulse	glycemic index	Context
06:00	80, 120	60	100	normal
14:00	90 130	75	210	emergent
23:00	88, 125	65	150	warning

The current status of patient generally depends on various elements. For example, temperature is coded to number, location is transcoded to some code, and body signal is converted to some interval value to express some symptom. Then, determining a context is not simple problem because of these variable context elements. The following table 1 is an example of training pattern of our ART1 model.

The glycemic index is generally featured before dining, 2 hours after dining, and before sleep. In case of diabetes patient, the glycemic index of 80 to 120 is shown before dining, less than 180 two hours after dining, and from 100 to 140 before sleeping. Based on these characteristics, table 2 shows a training pattern in 06:00, 14:00, and 23:00(before dining, 2 hours after dining, and before sleeping each). In this example, a patient shows normal status in before dining, emergent status in 2 hours after dining because the glycemic index exceeds 200, and warning status in before sleeping.

There are various events in home activities. Whereas the glycemic index in diabetes is the most important, the other elements such as blood pressure, pulse, and time can also help doctor making a medical treatment. In our model, the context is divided in three kinds: the normal state means ordinary in diabetes patients, warning state is not dangerous but needs caution, and emergent state means critical.

V. EXPERIMENT RESULTS

In this chapter, we show the experiment results which are the degree of context awareness that is measured with body sensor disposed in experimental home when a diabetes patient does daily activities. These sensors form a sensor network that output samples periodically.

Table 3 shows the value of context recognition as the rows are real measurement and the columns are predicted values by the pattern recognition algorithm.

By the way, we used a fictitious set of glycemic index because the inspection needs real blood. The numbers of samples are 1,660 in our experiment. Here we can see that right recognition rate of normal state is 88.4%, warning state 90.9, and emergent state 89.5 with the average rate 89.6%.

Table 3. Result of context awareness

real \ awareness	*normal*	*warning*	*emergent*
normal	88.4	6.0	5.6
warning	4.2	90.9	4.9
emergent	6.1	4.4	89.5

Also, the false rate that recognizes normal to warning and emergent is 6.0%, 5.6% respectively. The false rate that recognizes warning to normal and emergent is 4.2%, 4.9% each. And, the false rate that recognizes emergent to normal and warning is 6.1%, 4.4% each. The overall error rates are 5.2%.

By the way, there is a limitation in our experiment in that this result depends on the training pattern for our ART1 network. However there is some contribution as this model can provide better medical service and more correct context recognition if real data is adopted in this network.

Ⅵ. CONCLUSION

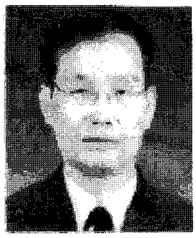
In this paper, we have implemented a prototype system for better medical service in which body sensor network is arranged around a diabetes patient with various sensors attached in one's body.

For context recognition, we used ART1 neural network in which four inputs such as time, blood pressure, pulse, and glycemic index forms a sensor network and three kind of output are emitted normal, warning, and emergent. The throughout experiment showed considerable recognition rates.

This model cannot recognize the current state perfectly but usefully guide a medical team and be utilized in other applications. For future research, we are to adapt out model to other diseases, verify this result, and develop context recognition based application.

REFERENCES

[1] Samsung SAIT, Ubiquitous world: e-health, CTO Information vol 72, 2002.
[2] Kalle Lyytinen and Youngjin Yoo, Issues and Challenges in Ubiquitous Computing, Communications of ACM, December 2002.
[3] EunKyung Lee, Ubiquitous computing projects, ETRI, 2003.
[4] Sunho Jang, Ubiquitous sensors, KIPS, 2005.
[5] Korea Health Industry Development Institute, ISP Report for Medical Information Sharing, 2000.
[6] HSookyung, Jinwook Choi, et al., Development of PDA Mobile Information System: MobileNurse, Korean, Society of Medical Informatics, vol 6, 2000.
[7] Kiuk Lee, Context monitoring based on ubiquitous sensor network, KISS journal, vol11, 2006.
[8] Jeongwon Kim, Implementation of ubiquitous blood pressure measurement system, Journal of KSCI , Vol11, 2006.
[9] http://www.tinyos.net
[10] M. Takemoto, The ubiquitous service-oriented network(USON), IEEE, pp17-21, Sept.2002.
[11] M. Takemoto, Service elements and service templates for adaptive service composition in a ubiquitous computing environment", IEEE Vol.1, pp335-338, Sept. 2003.
[12] M. Takemoto, A Service-Compositon and service-Emergence Framework for ubiquitous computing envrionment:, IEEE, Jan. 2004.
[13] http://www.cooltown.hp.com
[14] http://www.disappearing-computing.net/
[15] http://www.nist.gov/smartspace
[16] http://www.research.microsoft.com/easyliving
[17] Lee SW, Mase K, Activity and location recognition using wearable sensors. IEEE Pervasive Computing 1(3):24--32, 2000.
[18] Intille S, Larson K, Kukla C (2000) House_n: The MIT home of the future project. Department of Architecture, Cambridge, MA
[19] Bian X, Abowd, GD, Rehg JM, Using sound source localization to monitor and infer activities in the Home. GA, Technical Report; GITGVU-04-20, 2004.
[20] Christensen HB, Using logic programming to detect activities in pervasive healthcare. In: International conference on logic programming. pp 21--436, 2002.
[21] Jesus Favela, Activity Recognition for Context-aware Hospital Applications: Issues and Opportunities for the Deployment of Pervasive Networks, Mobile Netw Appl 12:155--171, 2007.
[22] http://www.hybus.net
[23] Daesu Kim, Neural network theory and applications, 1995.
[24] James A. Freeman, David M. Skapura, Neural Networks Algorithms, applications, and Programming Techiques, Addison Wesley, pp. 89-125, 1991.



Jeongwon Kim is an associate professor of Computer Information and Engineering at Silla university. His current interests include embedded system, ubiquitous health care, and pervasive computing. He has also received master and doctor degree in Pusan National University. He is a member of KIMICS, KSCI,etc.