The Journal of Digital Policy & Management 2013 Jul; 11(7): 261-269

u-Health 서비스를 위한 스마트폰용 스펙트럼 측정 시스템 개발

김동수[*], 이서준[**], 이태로[***]
고려대학교 일반대학원 보건과학과 박사과정[*], 고려대학교 일반대학원 보건과학과 석사과정[**],
고려대학교 보건행정학과 교수[***]

Development of Smart Phone Application With Spectrometer for u-Health Service

Dong-su Kim[*], Seo-joon Lee[**], Tae-ro Lee[***]
Korea University Graduate School Health Science Doctor's Course[*]
Korea University Graduate School Health Science Master's Course[**]
Korea University, Dept of Healthcare Management Professor[***]

요 약 u-Health는 최근 기술이며 의료 진단과 건강관리를 위한 새로운 방법론이다. 그러나 이를 실현하려면 몇 가지 기술적 장벽들(이동성, 소형화, 배터리 수명 문제 등)을 넘어서야 한다. 본 논문에서는 u-Health 서비스에 적합한 스마트폰용 스펙트럼 측정 시스템을 개발하였다. 실험 결과 기존 솔루션에 비해 무선이면서 크기가 매우 작지만 성능 면(재현성 비교실험에서 Spectrum, Calibration Curve, Prediction)에서 거의 일치한다는 것을 확인하였다. 따라서 개발된 솔루션은 u-Health 분야에서 널리 활용되어질 것으로 기대된다.

주제어 : u-Health, 스마트폰, BAN 통신, 스펙트럼 측정, 솔루션

Abstract Ubiquitous healthcare is a recent technology and a new methodology of medical diagnosis and medical care. However, in order for u-Healthcare service to become a general technology, there are some technological barriers(mobility, minimization, battery consumption etc) to overcome. In this paper, we developed a spectrum analysis system for smart phones. The results showed that compared to other solutions, our's were not only small in size but also almost the same in performance(reproducibility comparison experiments, Spectrum, Calibration Curve and Prediction). Therefore, the proposed solution is expected to be widely used in u-Health area.

Key Words : u-Health, Smart Phone, BAN Communications, Spectrum Analysis, USN

Received 8 May 2013, Revised 28 May 2013
Accepted 20 July 2013
Corresponding Author: Tae-ro Lee(Korea University, Dept of Healthcare Management Professor)
Email: trlee@korea.ac.kr

ISSN: 1738-1916

1. Introduction

Medical environment is rapidly changing. Higher income and higher proportion of elderly population has triggered the demand for well-being. As time goes by the government is spending more and more expenses on national health insurance, support for senior citizens, and chronic diseases[1] etc.

On the other hand, the fast growth of IT(Information Technology) industry in South Korea has increased the possibility to solve such problems through high-class IT technology[2]. Now that the medical field is perceived as an industry, medical professionals are turning their eyes on making profits through medical service.

Under these circumstances, u-Health can be seen as a new-growth engine industry through which the decrease in medical expenses, the desire for well-being, consumer-centric medical services, and the new u-health revenue model can be achieved[3]. In almost all areas, such as medical terms, social terms, technological terms, industrial terms, u-Health has its meaning.

True, spectrometer based on wire communication with PC is widely used nowadays to measure unidentified materials. Nevertheless, recent models are rarely compatible for mobile u-healthcare applications because none of the currently developed spectrometers are designed to be compatible for mobile devices. However, this paper will focus on minimized spectrometer models which has such compatibility.

So obviously, although the need for u-Health is urgent, there are many technological barriers to overcome. To overcome such adversities, an individualized healthcare model[4] needs to be designed. Also, developing more types of convenient medical devices that are compatible with personal smart phones is recently deemed as a powerful solution[5][6][7], which is what this paper will focus on.

Therefore, we propose a spectrometer attached smart phone application suitable for u-Health. In section 2, we will take a look at some related research and technologies. In section 3, system description will be presented in detail. In section 4, the result of our experiment will be evaluated. Finally in section 5, conclusion and further study of our proposed application will be discussed.

2. Related Research

The latest generation of smart phones are increasingly viewed as handheld computers rather than as phones, due to their powerful on-board computing capability, capacious memories, large screens and open operating systems that encourage application development[8]. Therefore it is often combined with u-Health systems. For example, an u-health system based on mobile phones equipped with a Bluetooth communication based pulse wave/oxygen saturation level reader was researched. It monitors patients through android smart phones[9]. This is highly similar to our proposed system, since we also use Bluetooth communication.

Another related technology is USN(Ubiquitous Sensor Network). USN is a technology in which small sensors are attached to buildings, roads, clothes or body parts to capture information concerning light, temperature, electromagnetic field, or velocity, and then communicate wirelessly. USN is applied in medical fields to sense bio-signals and provide these bio-signals to medical staff without limitations in time or space. Therefore, medical staff can provide remote medical service, and not only that, the potential applicable field of USN is increasing day by day. USN is crucial to u-Health technology, in fact, many u-Health related researches often use USN products such as Zigbee or RFID(Radio Frequency Identification). As an example, a sensor module using Zigbee that analyzes body fat, blood pressure and SpO^2

available for domestic use was developed. Along with such device, a wireless network healthcare server was built so that the patient's medical data could be monitored and sent online to a physician or guardian, even if the patient was at home[10], [11]. Compared to this model, our model also includes this kind of feature.

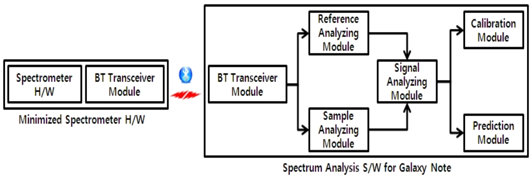
Also, to analyzes bio-signals and monitor a patient's health status, or in other words, to provide u-Health service, the following technologies can compromise a solution. First, spectrometers using infrared rays to sense bio-signals. Second, features of sending these bio-signals via BAN(Body Area Network) to personal smart phones, and the technology to analyze this signal. Third, inventing smart phones, communication protocols and analysis algorithm that includes calibration and prediction functions to support such tasks. In recent research, as an enhanced quantitative method than the existing uroscopy, measuring sugar and protein in urine through mid-infrared spectroscopy based on part-least-square method was developed. This method analyzes the wavelength of each components(sugar in urine and protein in urine) in order to get their density[12]. However, the critical flaw of this research(including most of the researches of uroscopy) is that the proposed uroscopy is only associated with computers, so to put it simply, is big in size. Also, it is safe to say that a solution using small sized spectroscopy system is needed. Therefore, it is safe to say that our solution that uses small sized spectroscopy is superior.

3. System Description

In this part of the section, the general specifications of smart phone based spectrum analysis system for u-Health service is described. When compared to other solutions that are commercially available, our solution is not only smaller in size but also the equal in performance. Our smart phone based analysis system is composed of 5 modules. (a) BT information exchange module, which exchanges real-time analyzed data through the proposed spectrometer. (b) Received data analysis module, which analyzes the received data and shows the result into a graph. (c) Spectrum conversion module, which manages the received data and analyzes their relations. (d) Optimal measurement detection module, which uses peak to leach out the valid data for modelling. (e) Microscopic sample analysis module, which uses the ultimately analyzed results(for example, density), to analyze the target material.

[Fig. 1] depicts the proposed u-Health system including the linkage between spectrometer H/W and android based smart phone(Galaxy Note).

Smart phone spectrum analysis system's main functions for the u-Health services consist of BAN communication between developed spectrometer and mobile devices, analyzing received data, spectrum conversion, optimal measurement detection, and analyzing minimized samples.



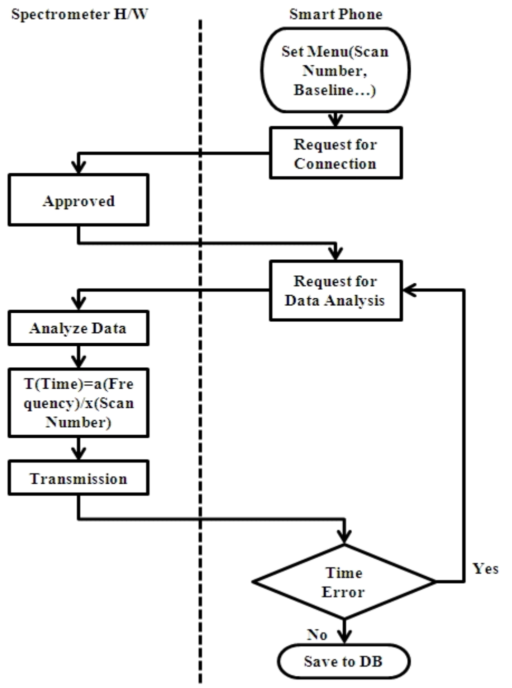
[Fig. 1] Proposed Configuration of u-Health System Between Spectrometer and Smart Phone

3.1 BAN communication between spectro-meter and mobile devices.

Using minimized sensor devices to monitor healthcare data anytime and anywhere is one of the most essential factors of u-Health service. Therefore, this research proposes a system in which a spectrometer module is connected to android based smart phones to receive real-time data anytime, anywhere through BT communication(a type of BAN).

[Fig, 2] shown below depicts the communication flow between the spectrometer module and the android smart phone.

The process starts when the user sets the menu to his/her desired features, such as a scan number or baseline. Then the smart phone communicates with the nearest spectrometer through Bluetooth and then, it sends a request for connection. After the request for connection is approved, the system sends another request to analyze data.

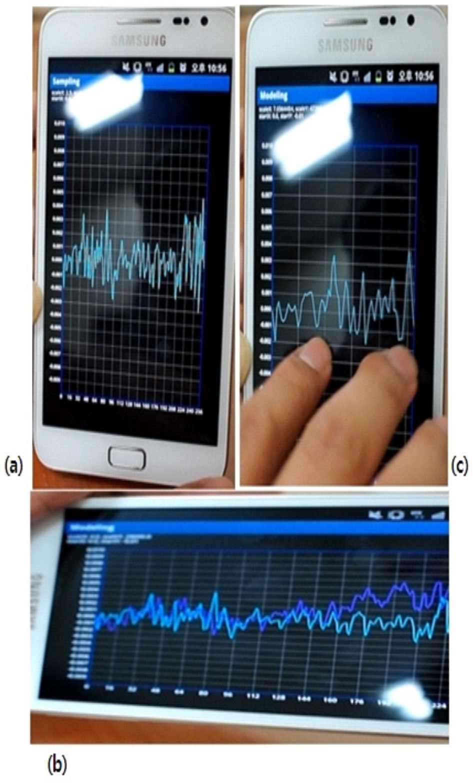


[Fig. 2] Communication Flowchart Between the Spectrometer and the Smart Phone

When analyzing the data, the spectrometer also computes the time 'T' by dividing the frequency by the scan number 'x'. The analyzed data is then transmitted to the smart phone where a time error is checked. If an error occurs, the process goes back to request for data analysis, otherwise the successfully transmitted data is saved to the database.

3.2 Displaying received data

After the data transmission, the transmitted data is displayed to the user. The data is accurately displayed in a graph of broken line. The screen shots shown below in [Fig. 3] are some examples of graph data displayed in a personal smart phone.



[Fig. 3] Screen Shot of Received Data and Graphic User Interface

For screen display we assigned sample numbers to horizontal axis and kinetic size to vertical axis, and the user can touch the phone screen and see the graph in detail. [Fig. 3](a) shows the graph in a vertical manner when the user sets the smart phone vertically. The graph displayed in the picture is extracted from the data received through Bluetooth. On the other hand, [Fig. 3](b) shows the graph in a horizontal manner when the user sets the smart phone horizontally. The graph size is automatically adjusted to the horizontally set smart phone screen. [Fig. 3](c) shows the graph in a close-up mode when the user uses his or her fingers to magnify the part where he or she wants to see more closely. The graph is programmed to react to this action, displaying the numerical figures more precisely.

3.3 Analyzing Spectrum

The data entered into the minimized spectrometer is divided into two types. One is the reference data and the other is the sample(the measured object) data. For instance, in making the reference data, materials like water is used, whereas in making the sample data, materials like glucose is used. Sample data is computed based on the data completed from the reference data. This procedure follows the sequence shown below.

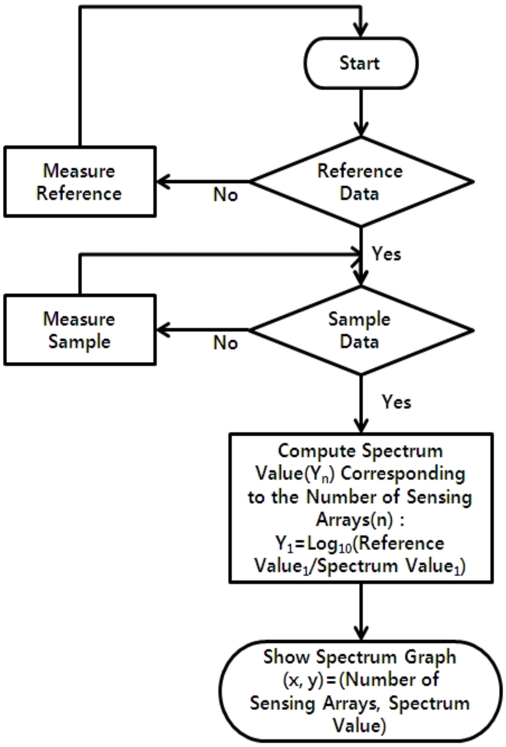
First, in order to get the spectrum information from the target sample through the spectrometer module, the signal must be analyzed. The spectrum information about the target sample is analyzed based on the reference. Both air and water may be most commonly used for reference value. But this can change according to the target sample, as long as the chosen reference value results in an optimal spectrum information.

Second, the reference is put on the spectrometer module to be analyzed. The data transmitted from the spectrometer module is the detected information.

Third, after analyzing the reference, the sample is put on the spectrometer module to be analyzed. Detected data results are saved to the database.

Lastly, the amount of detected reference data and sample data are set according to the same amount of the sensing array. Using logarithmic function, the calculated data are combined into a spectrum.

In the case when the spectrum is analyzed from the dynamic range samples fit for modeling, the density value received from this data is saved along with the spectrum data. These saved data are then used for calibration procedures which will be used for prediction. The specific details will be explained in section 3.4.

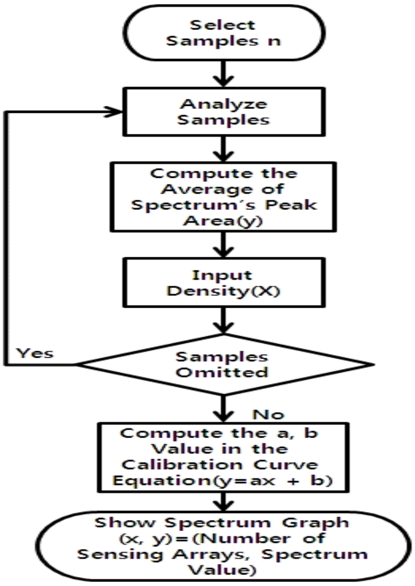


[Fig. 4] Analysis Flowchart of the Spectrometer

3.4 Calibration Curve for Optimal Extraction Features

Every material have molecule motion therefore have each of their own unique spectrum peak. Also, the spectrum peak varies according to density. If you can calculate the right mathematical formula between the density and the spectrum peak, it possible to gain the spectrum peak value from any material analyzed by the spectrometer, and use it to calculate the sample's density. The process to get the mathematical formula of optimal calibration curve is shown in [Fig. 5].

First, the samples of glucose standard density dynamic range(0, 20, 50, 100, 200, 300, 500, 1000mg/dl) are used for modeling. Then, the glucose spectrum data analyzed from the spectrometer is gained. Thirdly, the sample's unique spectrum peak is set and the average value is calculated. The mathematical formula of the correlation between the ‘Standard density set(x)’ and ‘Peak area average set(y)’ are calculated through least square technique. This formula results in a linear expression of ‘y= ax + b’, and this formula becomes the calibration curve. The standard of showing the correlation between these two sets(x and y) is the value of R^2. When the data does not match but is near the line, it has a value close to 1. Contrarily, when the data is distributed evenly and is not near the line, it has a value close to 0.



[Fig. 5] The Calculation Flowchart of Optimal Calibration Curve

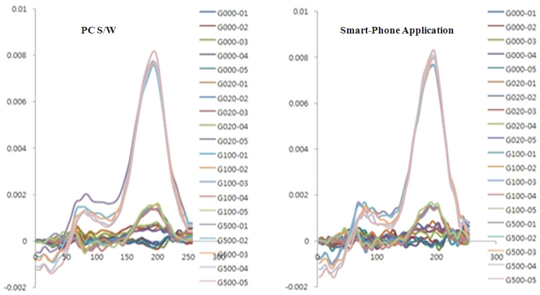
3.5 Analysis of Target Samples

After applying the mathematical formula of optimal calibration curve to the target sample, the following procedures must be followed to induce the density of that target sample. Initially, use the prediction function when you want to know the glucose density of the target sample. Then secure the dynamic range modeling and the calibration curve of the target sample glucose, and analyze the spectrum of the target sample. Finally, calculate the average of the peak area value that you used for modeling and inducing calibration curve. The sample data is calculated in the following order using the reference data.

Use the ‘y’ value induced from the mathematical formula between the ‘Density set(X)’ and ‘Peak area set(y)’ : y= ax + b. Substitute the ‘y’ value to gain the density value(x). In other words, if you substitute the ‘y’ value to ‘x = (y-b)/a’, you induce the ‘x’ value which naturally becomes the density value of the target sample.

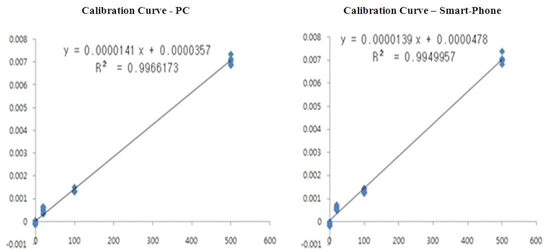
4. Results

Reproducibility comparison experiment and optimal calibration curve comparison experiment between the data induced through serial communication with PC and the data from smart phone(4 glucose standard samples, with each density of 0, 20, 100, 500mg/dL) using BAN communication was conducted. In [Fig. 6], the Y axis means the sample’s density and the X axis means the wavelength of the sample. The graph shows the glucose spectrum pattern and the peak is shown in 200 pixel(The experiment was repeated 5 times in each density). The density results from the reproducibility comparison experiment conducted in PC were the same as the results conducted in smart phone.



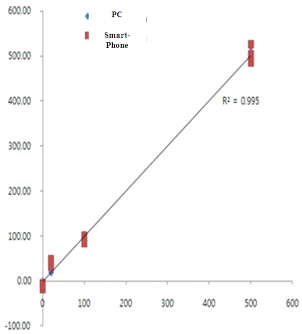
[Fig. 6] Comparing the Spectrum of Glucose Sample Reproducibility Comparison Experiment

In optimal calibration curve comparison experiment in [Fig. 7], the standard R^2 represents the match similarity between the two data sets. If the two data do not match but are close to a line, R^2 will have a value near 1. In the density experiment that was repeated 5 times, the results from PC and smart phone were almost the same, as shown in [Fig. 8].



[Fig. 7] Comparing the Calibration Curve of Glucose Sample Reproducibility Comparison Experiment

Sample	Density	PC	Smart-Phone
G000-01	0	-7.43	-5.25
G000-02	0	0.11	-18.56
G000-03	0	-13.56	-12.81
G000-04	0	-9.54	-6.10
G000-05	0	-8.51	-12.85
G020-01	20	42.89	34.95
G020-02	20	34.67	39.72
G020-03	20	28.66	41.50
G020-04	20	20.04	47.52
G020-05	20	41.21	31.39
G100-01	100	89.39	87.74
G100-02	100	91.25	96.31
G100-03	100	90.07	88.80
G100-04	100	91.96	83.66
G100-05	100	103.69	99.84
G500-01	500	485.02	502.61
G500-02	500	489.52	485.50
G500-03	500	499.25	496.39
G500-04	500	505.05	498.92
G500-05	500	519.73	525.69



[Fig. 8] Comparing the Prediction of Glucose Sample Reproducibility Comparison Experiment

Research results evidently showed that spectrometers could be linked with smart phones without any communication malfunction. That is, in other words, our module's features were not inferior compared to other modules. Also our spectrometer model is minimized, which has high mobility and convenience.

5. Conclusion

Analyzing materials using optics has been applied in a variety of study fields. However, the shortcomings of the prior researches concerning urine analysis using spectrometer are that they connected the spectrometers to large sized FTIR(Fourier Transform Infrared Spectroscopy) devices and PCs, instead of minimized personal devices[13]. Also, in most cases, these technology was usually used for analyzing, and not monitoring[14].

However, this research proposes small sized spectrometers to be linked wirelessly with mobile personal devices such as smart phones, which is expected to be suitable for u-health services.

From the spectrum of glucose sample reproducibility comparison experiment, the results showed that the PC and smart phone showed no significant difference. Also, the calibration curve comparison results showed that the performance of PC and smart phone was almost exactly the same. The prediction was also the same from spectrometers linked to smart phones and that of spectrometers linked to PCs. Therefore, this paper's research results evidently showed that spectrometers could be linked with smart phones without any communication malfunction. The proposed solution is now being evaluated for commercialization, and further study about the satisfaction of our solution is expected to be implemented.

Our solution is expected to be widely used by users to self-analyze their own health status. In fact, the proposed solution is now being evaluated for commercialization due to our highly practical features. However, against all positives, there are institutional and social barriers that deters the chance of success of our developed solution. Further study about the institutional and social barriers to overcome is expected to be implemented, along with how much impact our solution will have on u-Health.

REFERENCES

[1] Hauswaldt J, Hummers-Pradier E, Junius-Walker U. Health Service Use Among Patients With Chronic or Multiple Illnesses, and Frequent Attenders. Dtsch Arztebl Int. pp. 814-20. 2012.

[2] Ahn ME, Choi GH. A Developmental Process of Telemedicine, e-Health & u-Health. J Korean Med Assoc. 2009.

[3] Kim J, Kim S, Kim H, Kim K, Lee CT, Yang S, et al. Acceptability of the Consumer-Centric u-Health Services for Patients with Chronic Obstructive Pulmonary Disease. Telemed e-Health. pp. 329-338. 2012.

[4] Chang HL, Shaw MJ, Lai FP, Ko WJ, Ho YL, Chen HS, et al. U-Health: an example of a high-quality individualized healthcare service. pp. 677-687. 2010.

[5] Ballagas R, Borchers J, Rohs M, Sheridan JG. The smart phone: A ubiquitous input device. IEEE Pervasive Comput. pp. 70-77. 2006.

[6] Kim YH, Lim IK, Lee JK. Study on efficient telemedicine system design for ambulance emergency situation. International Journal of KIMICS. pp. 89-94. 2011.

[7] Toh SH, Lee SC, Lee HJ, Do KH, Chung WY. Mobile u-Health system in IEEE 802.15.4 WSN and CDMA network environments. Journal of the Korean Sensors Society. pp. 337-342. 2009.

[8] Boulos MNK, Wheeler S, Tavares C, Jones R. How smart phones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX. Biomedical engineering online. 2011.

[9] Kim G-H. Ubiquitous Health Care Smart System base on Bluetooth. The Journal of the Korean Institute of Information and Communication Engineering. 2012.

[10] Jang MS, Shin GS, Jung JH, Lee YH, Sim JH, Lee EH, et al. Design and implementation of u-healthcare system with zigbee in service integration system. Journal of the Institute of Electronics Engineers of Korea. pp. 16-24. 2006.

[11] Kim YJ, Jung IK, Yang YH, Kim BN, Lee IS. Design and implementation of an real-time bio-signals monitoring system using zigbee and SIP. Institute of Electronics Engineers of Korea. pp. 62-69. 2008.

[12] Yoon GW. Measurement of glucose and protein in urine using absorption spectroscopy under the influence of other substances. Korean Journal of Optics and Photonics. pp346-353. 2009.

[13] Kang N, Kasemsumran S, Woo YA, Kim HJ, Ozaki Y. Optimization of informative spectral regions for the quantification of cholesterol, glucose and urea in control serum solutions using searching combination moving window partial least squares regression method with near infrared spectroscopy. Chemometr Intell Lab. pp. 90-96. 2006.

[14] Jeong Y, Yang Y. Development of Tight-fitting Upper Clothing for Measuring ECG -A Focus on Weft Reduction Rate and Subjective Assessment. Journal of the Korean Society of Clothing and Textiles. pp. 1174-1185. 2012.

Dong-su Kim

- Feb 1988 : Young Nam University, Polymer Science
- Feb 2011 : Korea University Business School
- Feb 2011 ~ Present : Korea University Graduate School Health Science Doctorate Course
- July 2007 ~ Present : Chief of Research Center, JSM Healthcare Inc.
- Sep. 2005 ~ Present : CEO, JSM Healthcare Inc.
- Areas of Interest : u-Healthcare, IT and BT Convergence related to diagnostic and prevention
- E-Mail : a.kim@jsmintl.com

Seo-joon Lee

- Feb. 2013 : Korea University, Healthcare Management,
- Feb. 2013 ~ Present : Korea University Graduate School Health Science Master's Course
- Areas of Interest : u-Healthcare, Bio-Informatics
- E-Mail : richardlsj@korea.ac.kr

Tae-ro Lee

- Feb. 1984 : Kwangwoon University, Computer Engineering
- Aug. 1989 : Kyunghee University Graduate School of Education, Computer Education Master's Degree
- Feb. 2001 : Kyunghee University Graduate School of Computer Engineering Doctor's Degree
- Sep. 2005 ~ Aug. 2006 : Visiting Professor of Griffith University
- Sep. 1996 ~ Present : Professor of Korea University, Healthcare Management
- Areas of Interest : Healthcare Information System, u-Healthcare, Management Information System, Signal Processing
- E-Mail : trlee@korea.ac.kr