Impact Objectives

- Help address the issue of our ageing population and the prolificacy of chronic diseases by formulating a low cost, efficient and adaptable health monitoring system
- Continue to develop and improve smart wearable health monitoring systems which will allow patients to continuously monitor their own conditions
- Further investigate the potential of the system-on-chip (SoC) technology to aid clinicians in the diagnosis and classification of diseases

New dimensions in smart wearable technology

***Professor Shuenn-Yuh Lee** discusses his innovative work on health wearables, which hopes to address existing issues and move the field of smart wearable technology forward*

Could you introduce yourself and your key research interests?

I received my BA from the National Taiwan Ocean University in 1988, and my Master's and PhD degrees from the National Cheng Kung University (NCKU), Taiwan, in 1994 and 1999, respectively.

I was an Associate Professor from 2006 and Professor from 2011 in the Department of Electrical Engineering at National Chung Cheng University. Since 2013, I have been a Professor in the Department of Electrical Engineering at NCKU.

My present research activities involve the design of analogue and mixed-signal integrated circuits including filter, high-speed analogue to digital converter (ADC)/digital to analogue converter (DAC), sigma-delta ADC/DAC, biomedical circuits and systems including wearable and implantable devices, low-power and low-voltage analogue circuits, and radio frequency (RF) front-end integrated circuits for wireless communications.

Can you explain more about your health wearables research?

I established the Communication and Biologic Integrated Circuit (CBIC) Lab to develop the interactive intelligent healthcare and monitoring system (IIHMS), which includes a body sensor network (BSN) and a local sensor network (LSN).

The BSN is the medium of communication between the wearable device (for example the wristband) and the portable facility (the mobile phone and personal digital assistant). The LSN is the intermediate medium between the portable facility (mobile phone or personal digital assistant) and healthcare centre (the computer or healthcare cloud). The 'Guard Patch: An intelligent wearable wireless system with IoT and biosignal acquisition' can be employed to achieve the requirement of IIHMS.

In order to achieve the objectives of the Guard Patch project, the hardware of wearable devices needs to be developed and the platform software established. The key foci in our health wearable research include analogue circuit design, digital circuit design, power management circuit design and RF circuit design in the field of integrated circuits, embedded system development and software interface development on the co-design of hardware and software. Moreover, we are developing biomedical products such as: an ECG patch – the goal of which is to develop a low-power, long-term wearable body sensor system-on-chip (SoC) for wireless electrocardiogram monitoring; smart clothes, which involve combining wearable devices and textile sensors with the concept of the Internet of Things (IoT) to create a wearable healthcare system; developing a portable and wireless urine detection system and platform for the prevention of renal and cardiovascular diseases; an epilepsy brain wave detection and stimulation system; an EEG signal measurement and electrical stimulation module; and an IoT-based platform for smart wearable devices.

Can you discuss the problems with current smart wearable technology you are aiming to address?

Existing challenges associated with current smart wearable technology include: low-power devices for long-term use; minimisation devices for comfortable wear; high-resolution biosignal acquisition for analysis; artificial intelligence signal processing technology for diagnosis; and hardware and software co-design for the development of healthcare platforms.

Could you talk about the IoT platform your team has developed, the problems it is capable of addressing and why you feel it is superior to alternative technologies?

The problems for current IoT systems we are addressing are: high power, high cost, lack of customisation for biomedical application, no minimisation, and no source codes for users.

The features of our IoT platform are: low power and low cost due to the development of integrated circuits, a micro printed circuit board with biosignal acquisition and communication, and customisation for biomedical application. Furthermore, source codes with apps and signal processing can be freely downloaded by users. ▶

Smart clothes for a healthy future

*Research underway at **National Cheng Kung University** in Taiwan, is exploring the exciting realm of wearable technologies, which could hold huge benefits for the medical industry*

The field of wearable technologies is a novel and promising emerging area that offers a number of benefits to users and healthcare professionals alike, enabling real-time monitoring of diseases, convenience and ease of use. Professor Shuenn-Yuh Lee of the Department of Electrical Engineering at National Cheng Kung University (NCKU), Taiwan, is immersed in this field and working on a project called 'Guard Patch: An intelligent wearable wireless system with IoT and biosignal acquisition'.

This area of research is becoming increasingly important given the context of a rapidly ageing population and associated considerations of the prolificacy of chronic diseases, growing awareness of cost and emphasis on the importance of health monitoring. 'Prevention is better than cure is an important concept in healthcare,' highlights Lee. 'To economise on the social cost and improve the quality of medical treatment, a platform capable of examination anywhere and anytime by itself should be developed, which can transmit personal examination data to the healthcare centre or hospital via the Internet or wireless communication systems.'

This led Lee to set up a research laboratory – the Communication and Biologic Integrated Circuit (CBIC) Lab – to develop the interactive intelligent healthcare and monitoring system (IIHMS). This system includes a body sensor network (BSN) and a local sensor network (LSN), with the BSN acting as the medium of communication between the wearable devices and the portable facility, and the LSN being the intermediate medium between the portable facility and the healthcare centre.

An example of the smart pet clothing for monitoring the health and mood of an animal

KEY AREAS

Key areas Lee's lab is focusing on are, first, the development of an ECG patch, on which they are working with start-up companies Nuworld Corporation and Yutech Corporation. 'Our team implements a high-resolution and low power biosignal acquisition chip,' Lee explains. 'We integrate the required circuits into a wearable system module to sense the ECG signal from users. The communication between the sensor and the smart phone is established via Bluetooth.'

The ECG patch software is required to follow four key tasks: data processing, analysis, display and recording. Further mathematical calculations and analyses are performed by a backend app on Android/iOS system. 'With the wearable platform for wireless biosignal acquisition, the user can access and monitor their own physiological condition anytime and anywhere,' highlights Lee. 'For these functions mentioned above, this wireless biosignal acquisition system will become the guard of the user.'

A second primary area the team is focusing on is smart clothes, in which the researchers are working to combine wearable devices and textile sensors with the concept of the Internet of Things (IoT) to create a wearable healthcare system. 'Smart clothes congenitally have the advantage among the applications of wearable devices,' explains Lee. 'First, unlike most systems such as watches and belts, clothes are necessary for everyone in daily life, so the related wearable devices can be easily accepted by others. Also, smart clothes can provide more variants on biosignal monitoring than other wearable devices because they have a larger area in contact with the body surface of the user.' The team is collaborating with clothing company Tien Jiang Enterprise Co. Ltd., to develop a smart clothes system that uses fabric-based electrodes, which are comfortable to wear and provide ECG signal and respiration signal measurement, and deliver the signal through Bluetooth to a mobile phone. Measurements of energy expenditure and heart rate variability can then be analysed.

Thirdly, the team is developing a portable and wireless urine detection system, in which the researchers are working to develop a system-on-chip (SoC), a microelectrode and microchannel chip to detect albumin, creatinine, cystatin C, NT-proBNP and troponin I concentrations in urine. The idea is that this information will then be wirelessly transmitted to a smart application platform to evaluate a user's renal and cardiovascular statuses based on the outcomes in a clinical research collaboration with Professor Ju-Yi Chen, a clinician at NCKU Hospital. Further projects focus on: developing an epilepsy brain wave detection and stimulation system, on which the team is collaborating with Professor Chou-Ching Lin, a clinician at NCKU Hospital; an EEG signal measurement and electrical stimulation module; and an IoT-based platform for smart wearable devices – a project that is supported by the Ministry of Education (MoE) and Ministry of Science and Technology (MOST) of Taiwan.

THE GUARD PATCH

The Guard Patch functions using integrated circuits the researchers have developed, including a biosignal acquisition system, digital signal processing system, power management system and wireless transceiver system. The products it encompasses have a number of advantages compared to existing systems. For example, the ECG patch has a low-power SoC for wireless electrocardiogram monitoring that can be used more days without wireless and the patch length can be adjusted to fit anybody. Regarding smart clothes, it can provide more detailed biosignal monitoring than other wearable devices because it has a larger surface area in contact with the body of the user. When it comes

> *Smart clothes can provide more variants on biosignal monitoring than other wearable devices because they have a larger area in contact with the body surface of the user*

to the portable and wireless urine detection system, the cost is lower, the product can be disposable, and can also be easily combined with integrated circuits to lower power consumption for long-term use on wearable devices. The epilepsy brain wave detection and stimulation system the team is working on includes EEG detection SoC and Bluetooth low energy (BLE) for wireless communication, enabling real-time detection, diagnosis and stimulation to be achieved. Lastly, the team's IoT-based platform for smart wearable devices is the only platform customised for biomedical application that can use the wearable devices to detect different biosignals.

The team believes the Guard Patch will benefit a plethora of people. For example, the researchers are confident the ECG patch, smart clothes and portable and wireless urine detection system will be of benefit to elderly patients and patients with heart disease. Meanwhile, the epilepsy brain wave detection and stimulation system will be invaluable for patients with epilepsy, while the IoT-based platform for smart wearable devices will benefit students, the electrical engineering industry and healthcare workers. In addition, the technology the team is working on is transferable to other smart devices as Lee explains: 'The iOS-base and Android-base apps are developed in the software platform.

Moreover, Bluetooth usually embedded in smart devices, is used for wireless communication. Therefore, it's easy to transfer the wearable devices to other smart devices.'

One of three prizes won at the 2017 Future Technology Show of MOST in Taiwan

A further novel line of investigation the team is engaged in is that of smart clothing for pets, prompted by the rapidly growing pet population and simultaneous growth of related industries. 'We targeted the area of heart disease in previous work,' explains Lee. 'According to a conservative statistical report, 11 per cent of dogs and 15 per cent of cats suffer from symptoms of congenital or age-related heart disease. For instance, aged cats often suffer from hypertrophic cardiomyopathy, and aged dogs commonly have valvular stenosis and insufficiency. Moreover, certain heart diseases, particularly in cats without evident clinical symptoms, probably cause sudden death. Therefore, early detection and long-term tracking may be necessary.'

The proposed smart pet clothing the researchers are developing seeks to assist owners in understanding the emotions and health of their pets in order to effectively care for them. The smart pet clothing is able to monitor these factors by measuring ECG and breath signals. 'This mechanism can diagnose possible cardiovascular diseases in pets through ECG signal analysis,' explains Lee. 'Combined with breath signals, the emotional response of pets can be understood.'

FUTURE PLANS

Looking ahead to the next five to 10 years, the researchers will be exploring the SoC technique in greater detail, with a view to further minimising their wearable device, low-power circuit design technique to fit the requirement of IoT, high-resolution circuit design technique to provide the de-noised biosignals that can be easily diagnosed by clinicians, and artificial intelligent hardware/software co-design technique to effectively classify diseases, thereby assisting clinicians. ●

Project Insights

FUNDING

This research was supported in part by the Chip Implementation Centre (CIC), Ministry of Education (MOE), Taiwan, R.O.C, and the Ministry of Science and Technology (MOST), Taiwan, R.O.C., under Grants MOST 106-2314-B-006-001 and MOST 107-2622-8-006-009 -TE2.

COLLABORATORS

Collaborators on the 'Guard Patch: An intelligent wearable wireless system with IoT and biosignal acquisition' include:

National Cheng Kung University (NCKU) Hospital, Taiwan • Yutech Corporation • Nuworld Corporation • Tien Jiang Enterprise Co. Ltd • Material and Chemical Research Laboratories, Industrial Technology Research Institute • Electronic and Optoelectronic System Research Laboratories, Industrial Technology Research Institute • Smart Microsystems Technology Center, Industrial Technology Research Institute

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Shuenn-Yuh Lee established the Communication and Biologic Integrated Circuit (CBIC) Lab in 2002. His mission is to build a user-friendly development platform with smart wearable systems, which consists of the biosignal processing integrated circuits and modules, the user-friendly websites and apps, and the artificial intelligence (AI) system on the cloud.