Biomedical Information Technology Laboratory

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BIT lab is seeking

to develop diversified modalities for persistent monitoring of various vital signs by making use of innovative measurement principles.

to perform theoretical simulation and data analysis by mathematical means to reveal statistical links between incidence of various diseases and dynamics of health condition.

to construct an integrated infrastructure SHIP(Scalable Healthcare Integrated Platform) for lifelong health promotion and seamless coverage of the care cycle from womb to tomb by full use of the latest ICT advancement.

to foster a new discipline Metrology of Health or Healthology to quantify the overall health status from an integrative standpoint and to untangle the causal connections among longevity and relevant determinants such as pathogeny and immunity, meteorological and environmental factors, and social-behavioral-psychoneurotic interactional aspects.

Prof. Chen's research activities continued focusing on the ICT-based healthcare domain to develop a long-term strategy for daily healthcare. Prof. Chen conducted several projects. These studies developed an Internet-based infrastructure, including a series of instrumentation for seamless monitoring of vital signs without disturbing subjects in daily life environment, and a variety of algorithms for in-depth data mining and Big Data analytics in biomedical application. Several cooperative studies with external institutions and companies were implemented for field trial and exploring possibility of commercialization. - A cooperative study with three nursing homes aimed to collect elderly data and to assess the system performance through field trial. - A cooperative study with Bange Welfare General Hospital collected clinical data from patients suffered from kidney disorder, and

evaluated the therapeutic effect during dialysis. - A cooperative study with Asahi Denshi Corp. developed an Umemory Server Array (USA) and various algorithms for sleep monitoring.

Prof. Zhu's research is focused on biomedical signal processing and cardiac modeling and simulation. His collaboration research supported by JSPS with Tohoku University is to develop a novel diagnostic method based on 12 lead ECG for atrial fibrillation. His collaboration research supported by JSPS with Toho University is to study the feasible implantation site of implantable cardioverter defibrillator using computer modeling and simulation. Currently, he is also studying the computer-aided diagnosis of colorectal and gallbladder cancer using deep learning with Aizu Medical Center.

Prof. Hisada's research relates of biological signal analysis and health care application. The estimation of mental health and the self-management support system for diabetic patient are focused. And he studies also the satellite observation field using microwave radar. The environmental monitoring of wetland using satellite is funded by Fukushima Prefectural Foundation for Advancement of Science and Education. The estimation of biomass by ground and satellite monitoring is cooperate with Tsuruoka National College of Technology, JAXA (Japan Aerospace Exploration Agency) and RESTEC (Remote Sensing Technology Center of Japan).

Refereed academic journal

[wenxi-306-014-01:2015] Zunyi Tang Wenxi Chen Ming Huang, Toshiyo Tamura and Shigehiko Kanaya. Structural Optimization of a Wearable Deep Body Thermometer: From Theoretical Simulation to Experimental Verification. *Journal of Sensors*, 2016:1–7, 2015.

Deep body temperature (DBT) has yet to be measured continuously in everyday life, even though it is useful in physiological monitoring and chronobiology studies. We tried to address this issue by developing a transcutaneous thermometer based on the dual-heat-flux method (DHFM) invoking the principle of heat transfer, for which measurement error was mitigated by elaborate design. First, a structural modification based on the original design of the DHFM was implemented by the finite element method. Based on the results of the simulations, prototypes were then implemented and tested with an experimental system that mimicked the thermometer being applied to skin. The simulation phase proposed the adoption of an aluminum cover to boost measurement accuracy and suggested that thermometers of different height be chosen according to specified requirements. The results of the mock-up experiments support the modification put forward in the simulation phase: the standard type (15mm in height) achieved the accuracy with error below 0.3 Celsius degree while the thin type (9mm in height) attained accuracy with error less than 0.5 Celsius degree under normal ambient temperature ranging from 20 to 30 Celsius degree.Even though the design should also be examined in vivo, it is believed that this study is an important step in developing a practical noninvasive deep body thermometer.

[wenxi-306-014-02:2015] Wenxi Chen Toshiyo Tamura. Seamless Monitoring of Physiological Information in Daily Life: Retrospectives and Perspectives. *Advanced Biomedical Engineering*, 4:86–95, 2015.

This paper reviews endeavors over the past decades to achieve seamless monitoring of various types of physiological information by a variety of high user-affinity approaches applicable to the daily life environment. Developments in academic research and commercialization from the early period are reviewed. The latest outcomes are briefly investigated and roughly categorized into three main models: miniature portable monitors for ambulatory application, functional fabric-based wearable monitors for better comfort, and unobtrusively deployed invisible monitors for optimum usability. Monitors for seamless monitoring of physiological information in the daily life environment differ from

conventional devices that are hospital-centered and aimed at short-term use in clinics. Through scrutinizing the current systems and examining their various pros and cons, we identify existing common concerns, provide insight into problem determinants, and suggest research topics for further study. In the near future, we envision that the home will be transformed into an intelligent hub for lifelong healthcare through seamless monitoring of the human body in the daily life environment, which will foster the development of a new discipline 'Metrology of Health' or 'Healthology' based on a holistic view of health.

[wenxi-306-014-03:2015] Kei-ichiro Kitamura Tetsu Nemoto Ying Chen, Wenxi Chen. Long-term Measurement of Maternal Pulse Rate Dynamics Using a Home-based Sleep Monitoring System. *Journal of Sensors*, 2016:1–11, 2015.

Major adaptations occur in the maternal cardiovascular system during pregnancy and after delivery; knowledge of these changes is essential to the health management of pregnant women. This paper presents a longitudinal study and proposes a methodology to monitor daily pulse rates (PRs) and characterize the weekly changes in maternal PRs before and after delivery. PRs were recorded during nightly sleep using an automatic monitoring system. PRs of the nonpregnant woman were taken as a reference. Weekly PR properties were characterized by histogram and a two-Gaussian mixture model. A coupling use of sample entropy and pulse rate was applied to cluster the stages during recovery period after delivery. Results depicted a profile of individual's cardiac recovery process in late pregnancy and after delivery. The results reveal that maternal PRs show different patterns in various stages of recovery. Later stages of recovery seemed to require a much longer period. The present study introduced a convenient approach in long-term maternal cardiac condition monitoring.

[wenxi-306-014-04:2015] Tang Z Chen W Kanaya S. Huang M, Tamura T. A Wearable Thermometry for Core Body Temperature Measurement and Its Experimental Verification. *IEEE J Biomed Health Inform.*, page Epub ahead of print, Feb. 2016.

A wearable thermometry for core body temperature (CBT) measurement has both healthcare and clinical applications. On the basis of the mechanism of bioheat transfer, we earlier designed and improved a wearable thermometry using the dualheat- flux method for CBT measurement. In this study, this thermometry is examined experimentally. We studied a fastchanging CBT measurement (FCCM, 55 min, 12 subjects) inside a thermostatic chamber and performed long-term monitoring of CBT (LTM, 24 h, 6 subjects). When compared with a

reference, the CoreTemp CM-210 by Terumo, FCCM shows 0.07 celsius degree average difference and a 95 percent CI of [-0.27, 0.12] celsius degree. LTM shows no significant difference in parameters for the inference of circadian rhythm. The FCCM and LTM both simulated scenarios in which this thermometry could be used for intensive monitoring and daily healthcare, respectively. The results suggest that because of its convenient design, this thermometry may be an ideal choice for conventional CBT measurements.

[zhuxin-306-014-01:2015] et al. Mahito Noro, Xin Zhu. Efficacy and Myocardial Injury With Subcutaneous Implantable Cardioverter Defibrillators - Computer Simulation of Defibrillation Shock Conduction-. *Circulation Journal*, 80(1), 1 2016.

Abstract Background: Subcutaneous implantable cardiac defibrillator (S-ICD) systems have a lower invasiveness than traditional ICD systems, and expand the indications of ICD implantations. The S-ICD standard defibrillation shock output energy, however, is approximately 4 times that of the traditional ICD system. This raises concern about the efficacy of the defibrillation and myocardial injury. In this study, we investigated the defibrillation efficacy and myocardial injury with S-ICD systems based on computer simulations. Methods and Results: First, computer simulations were performed based on the S-ICD system configurations proposed in a previous study. Furthermore, simulations were performed by placing the lead at the left or right parasternal margin and the pulse generator in the superior and inferior positions (0-10 cm) of the recommended site. The simulated defibrillation threshold (DFT) for the 4 S-ICD system configurations were 30.1, 41.6, 40.6, and 32.8 J, which were generally similar to the corresponding clinical results of 33.5, 40.4, 40.1, and 34.3 J. Conclusions: The simulated DFT were generally similar to their clinical counterparts. In the simulation, the S-ICD system had a higher DFT but relatively less severe myocardial injury compared with the traditional ICD system. Further, the lead at the right parasternal margin may correspond to a lower DFT and cause less myocardial injury.

[zhuxin-306-014-02:2015] Xin Zhu and Mahito Noro. Recent Progress in ICD Programming and Configurations for Reducing Inappropriate Therapy and Mortality. *Nanotechnology and Precision Engineering*, 13(5):9–16, 5 2015.

Abstract Implantable cardioverter-defibrillators (ICDs) are the most important and effective tool for the primary and secondary prevention of sudden cardiac death (SCD). However, inappropriate and unnecessary ICD therapy

(shocks or anti-arrhythmia pacing (ATP)) causes myocardial injuries and therefore may worsen prognostics and increase all causes of mortality. ICD systems also cause infections and complications, and should be removed completely. Recently, optimum ICD programming has been proposed to reduce inappropriate and unnecessary therapies. Progress such as subcutaneous ICD (S-ICD) and the populariy of single-coil lead may also reduce the infections and complications of ICD implantation. In this review, the causes of inappropriate and uncessary ICD therapies were introduced at first. Then we described recent clinical trials on ICD programming related to zones programming, detection duration, supraventricular tachycardia (SVT) discrimination algorithms, and T wave oversensing. Trends of ATP, S-ICD, the choice of single- or dual-coil leads were also explained and discussed. In conclusion, the safety and efficacy of ICD programming have been proved based on randomized and non-randomized clinical trials, and inappropriate and unnecessary therapy has been reduced to less than 3 percent cases using optimum ICD programming and configurations. Future patient-specific ICD programming and configuration based on clinical evidence from clincal trials may further minimize ICD inappropriate and unnecessary therapies and complications, and therefore minimize myocaridial injuries and all causes of mortaliy caused by ICD therapy.

[zhuxin-306-014-03:2015] Xin Zhu Wenxi Chen Koji Fukuda Yi Zheng, Daming Wei and Hiroaki Shimokawa. Ventricular fibrillation mechanisms and cardiac restitutions: an investigation by simulation study on whole-heart model. *Computers in Biology and Medicine*, 63(6):261–268, 6 2015.

Abstract Background The action potential duration (APD) and the conduction velocity (CV) restitution have been reported to be important in the maintenance and conversion of ventricular fibrillation (VF), whose mechanisms remain poorly understood. Multiple-wavelet and/or mother-rotor have been regarded as the main VF mechanisms, and APD restitution (APDR) and CV restitution (CVR) properties are involved in the mutual conversion or transition between VF and ventricular tachycardia (VT). Methods and Results The effects of APDR (both its slope and heterogeneity) and CVR on VF organization and conversion were examined using a rule-based whole-heart model. The results showed that different organizations of simulated VF were manifestations of different restitution configurations. Multiple-wavelet and mother-rotor VF mechanisms could recur in models with steep and heterogeneous APDR, respectively. Suppressing the excitability either decreased or increased the VF com-

plexity under the steep or shallow APDR, respectively. The multiple-wavelet VF changed into a VT in response to a flattening of the APDR, and the VT degenerated into a mother-rotor VF due to the APDR heterogeneity. Conclusions Our results suggest that the mechanisms of VF are tightly related to cardiac restitution properties. From a viewpoint of the rule-based whole-heart model, our work supports the hypothesis that the synergy between APDR and CVR contributes to transitions between multiple-wavelet and mother-rotor mechanisms in the VF.

[zhuxin-306-014-04:2015] Daming Wei Weimin Xu Wenfeng Shen, Zhaokai Luo and Xin Zhu. Load-prediction scheduling algorithm for computer simulation of electrocardiogram in hybrid environments. *Journal of Systems and Software*, 102:182–191, 4 2015.

Abstract This paper proposes an algorithm that allows fully utilize the Central Processing Unit-Graphics Processing Unit (CPU-GPU) hybrid architecture to conduct parallel computation and reasonable scheduling for computer simulation of electrocardiogram (ECG). This algorithm is realized by accelerating calculation speed and increasing platform adaptability of the parallel algorithm.

Refereed proceedings of an academic conference

[wenxi-306-014-05:2015] Wenxi Chen Naoki Ono Tetsuo Sato Shigehiko Kanaya Ming Huang, Toshiyo Tamura. Evaluation of a Noninvasive Deep Body Thermometer in Measurement of Specific Positions. In *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 2015.

[wenxi-306-014-06:2015] Toshiyo Tamura Masaki Yoshida Wenxi Chen Zunyi Tang, Masaki Sekine. A Chair for Cuffless Real-Time Estimation of Systolic Blood Pressure based on Pulse Transit Time. In *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 2015.

[wenxi-306-014-07:2015] Wenxi Chen Chen Ying, Zhu Xin. Automatic Sleep Staging based on ECG Signals using Hidden Markov Models. In *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 2015.

[wenxi-306-014-08:2015] Toshiyo Tamura Wenxi Chen. Detection of Indiscernible Information from Daily Physiological Data Over a Long-Term Period. In *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 2015.

[wenxi-306-014-09:2015] Takeshi Nagahiro Yosuke Aoyagi Takahiro Tokumiya Wenxi Chen Ying Chen, Ai Hirasawa. Acute Effects of Alcohol on Augmentation Index, Radial Artery Pressure, and Pulse Rate. In *u-Healthcare 2015*, November 2015.

[wenxi-306-014-10:2015] Yosuke Aoyagi Wenxi Chen Ai Hirasawa, Takeshi Nagahiro. Estimation of vascular age with augmentation index. In *u-Healthcare 2015*, November 2015.

[zhuxin-306-014-05:2015] Wenxi Chen Kei-ichiro Kitamura Xin Zhu, Xina Zhou and Tetsu Nemoto. Awareness of Sleep and Life Styles in Nursing Home Residents Using a Unconstrained Monitoring System. In Xin Zhu, editor, *Position Paper IEEE iCAST2015*. Northeaster University at Qinhuangdao, China, IEEE, 2016.

In this research, we used a so-called Yumenary system to aware the sleep and life styles of 13 nursing home residents for a total of 1,090 days in 2 nursing homes in Fukushima Prefecture, Japan.

[zhuxin-306-014-06:2015] Wenxi Chen Chen Ying, Xin Zhu. Automatic Sleep Staging based on ECG Signals using Hidden Markov Models. In IEEE EMBS, editor, *Conf Proc IEEE Eng Med Biol Soc.* IEEE EMBS, IEEE EMBS, 8 2015.

Abstract This study is designed to investigate the feasibility of automatic sleep staging using features only derived from electrocardiography (ECG) signal. The study was carried out using the framework of hidden Markov models (HMMs). The mean, and SD values of heart rates (HRs) computed from each 30-second epoch served as the features. The two feature sequences were first detrended by ensemble empirical mode decomposition (EEMD), formed as a two-dimensional feature vector, and then converted into code vectors by vector quantization (VQ) method. The output VQ indexes were utilized to estimate parameters for HMMs. The proposed model was tested and evaluated on a group of healthy individuals using leave-one-out cross-validation. The automatic sleep staging results were compared with PSG estimated ones. Results showed accuracies of 82.2, 76.0, 76.1 and 85.5 percent for deep, light, REM and wake sleep, respectively. The

findings proved that HRs-based HMM approach is feasible for automatic sleep staging and can pave a way for developing more efficient, robust, and simple sleep staging system suitable for home application.

Unrefeered proceedings of an academic conference

[wenxi-306-014-11:2015] Kazuki Miwa Wenxi Chen, Ying Chen. Effect of Bath Powder on Heart Rate Variability during Bathing. In *The 49th Northeast Branch Conference of Japanese Society for Medical and Biological Engineering*, page 32, November 2015.

Research grants from scientific research funds and public organizations

[wenxi-306-014-12:2015] Wenxi Chen. Fukushima Prefecture Medical and Welfare Equipment Development Project, 2015.

Academic society activities

[wenxi-306-014-13:2015] Wenxi Chen, 2015.

Division of Life Engineering Executive Member and International Member

[wenxi-306-014-14:2015] Wenxi Chen, 2015.

New Technology Development Award Selection Committee Member

[wenxi-306-014-15:2015] Wenxi Chen, 2015.

Medical equipment related industry human resource development support project review committee member

[zhuxin-306-014-07:2015] Xin Zhu, 9 2015.

Program Chair of IEEE iCAST2015

Patent

[wenxi-306-014-16:2015] Toshiyo; Chen Wenxi Huang, Ming; Tamura. DEEP BODY THERMOMETER, Sept 2015.

[zhuxin-306-014-08:2015] Xin Zhu and Mahito Noro. Computer simulation of defibrillation currents and computer simulation device for ICD implantation sites, 2015.

Advisor for undergraduate research and graduate research

[wenxi-306-014-17:2015] Hikaru Sasaki. Master, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-18:2015] Kazuki Yamamoto. Master, University of Aizu, March 2015.

Referee

[wenxi-306-014-19:2015] Michiro Miyauchi. Graduation thesis, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-20:2015] Yuki Obayashi. Graduation thesis, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-21:2015] Masayuki Watanabe. Graduation thesis, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-22:2015] Miki Karuki. Graduation thesis, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-23:2015] Yuka Chiba. Graduation thesis, University of Aizu, March 2015.

Supervisor

[wenxi-306-014-24:2015] Naoya Miyazawa. Graduation thesis, University of Aizu, March 2015.

Referee

[wenxi-306-014-25:2015] Tsukasa Aketagawa. Graduation thesis, University of Aizu, March 2015.

Referee

[wenxi-306-014-26:2015] Kiyoshi Suzuki. Graduation thesis, University of Aizu, March 2015.

Referee

Scholarly paper prepared by undergraduate/graduate student(s) you advised

[wenxi-306-014-27:2015] Yosuke Aoyagi Wenxi Chen Ai Hirasawa, Takeshi Nagahiro. Estimation of vascular age with augmentation index. *u-Healthcare 2015*, 2015.

Advisor of a student club or circle

[wenxi-306-014-28:2015] Planning and Development Group

Contribution related to faculty personnel (outside scouting, etc.)

[wenxi-306-014-29:2015] Faculty Selection Committee Member

Contribution related to educational research technology and facility planning management

[wenxi-306-014-30:2015] SR Evaluation Committee Curriculum Subcommittee Tenure Acquisition Qualification Review Committee Robot Information Technology Cluster Opening Preparation Office Member Competitive Research Funding Evaluation Committee Cooperative Research Evaluation Committee Faculty Recruitment Committee Research Ethics Committee Job Invention Board Graduate School Entrance Examination Committee Conflict of Interest Committee

Contributions related to regional education

[wenxi-306-014-31:2015] Visiting lecture: Shirakawa High School

Proposal/implementation of a new industry

[wenxi-306-014-32:2015] Fukushima Prefecture Medical and Welfare Equipment Development Project

Did you participate in Public Lectures, and/or Open Campus? (Yes or No) If yes, please describe what you did.

[wenxi-306-014-33:2015] Participation in Open Labs 2015 -Summer session and Autumn session- Research Theme/Title:Seamless Monitoring and Comprehensive Interpretation of Physiological Information for Daily Healthcare

Do you have experience of University-Industry collaboration? If yes, please describe your experience. (for UBIC's information)

[wenxi-306-014-34:2015] Fukushima Prefecture Medical and Welfare Equipment Development Project