

Biomedical Information Technology Laboratory



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BIT lab is seeking to develop diversified modalities for persistent monitoring of physiological information by making use of various physical and chemical principles. perform theoretical simulation and data analysis by mathematical means to reveal statistical links between incidence of various diseases and dynamics of health condition. 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 achievement. 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 health-care 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 two 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 suffering from chronic diseases, and evaluated the therapeutic

effect during treatment. A cooperative study with Lixil Corp. developed a new model of bedside monitor for sleep monitoring system. A cooperative study with Asahi Denshi Corp. developed an Umemory Server Array (USA) and various algorithms for sleep monitoring. Prof. Hisada's research relates of biological signal analysis and signal processing circuit. The real-time estimation of sleep stage is 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). 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.

Refereed Journal Papers

[wenxi-01:2013] Kazuhiro Ogai Xin Zhu Kei-Ichiro Kitamura, Ryuya Takeuchi and Wenxi Chen. Development of a novel pulse wave velocity measurement system: Using dual piezoelectric elements. *Medical Engineering & Physics*, February 2014.

The aim of this study is to develop a painless system of measuring the brachial-ankle arterial pulse wave velocity (baPWV) without compression cuffs. The PWV reflects the compliance of the artery and is measured for the early diagnosis of arteriosclerotic vascular diseases. However, the conventional baPWV system, which measures four cuff pressures simultaneously, easily causes circulation block and tightening pain at the extremities. In addition, approximately 15min are required to stabilise the blood pressure for re-examination. Therefore, we developed a novel baPWV measurement system using dual piezoelectric sensor elements. The principle of this high-sensitivity pressure pulse detection system is based on adding the two in-phase outputs from the coaxially arranged dual piezoelectric sensor. As our system facilitates the measurement of the baPWV by detecting the pulsation of an artery using sensors fixed on the skin where the pulse is palpable, it does not cause pain and reduces examination time. The coefficients of correlation between the baPWV values obtained from the conventional and present methods were 0.93 (right side) and 0.90 (left side). The results suggest that our system can be used to measure the baPWV without pressure cuffs as accurately as the conventional method.

[zhuxin-01:2013] Hikaru Hashimoto Naoshi Ito Yoshinari Enomoto Shingo Kujime Tsyoshi Sakai Takao Sakata Yasuhiro Oikawa Kazuya Murakami Hiroyuki Tatunami Mahito Noro, Xin Zhu and Kaoru Sugi. 植込み型除細動器作動時の伝導様式に基づく、出力抑制による心筋障害抑制の検討. *Shinzo*, pages 202–210, 2013.

植込み型除細動器作動時の伝導様式に基づく、出力抑制による心筋障害抑制の検討

[zhuxin-02:2013] Kei-Ichiro Kitamura, Ryuya Takeuchi, Kazuhiro Ogai, and Wenxi Chen Xin Zhu. Development of a novel pulse wave velocity measurement system: Using dual piezoelectric elements. *Medical Engineering & Physics*, page NA, 2014.

Available online 25 March 2014 The aim of this study is to develop

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a painless system of measuring the brachial-ankle arterial pulse wave velocity (baPWV) without compression cuffs. The PWV reflects the compliance of the artery and is measured for the early diagnosis of arteriosclerotic vascular diseases. However, the conventional baPWV system, which measures four cuff pressures simultaneously, easily causes circulation block and tightening pain at the extremities. In addition, approximately 15 min are required to stabilise the blood pressure for re-examination. Therefore, we developed a novel baPWV measurement system using dual piezoelectric sensor elements. The principle of this high-sensitivity pressure pulse detection system is based on adding the two in-phase outputs from the coaxially arranged dual piezoelectric sensor. As our system facilitates the measurement of the baPWV by detecting the pulsation of an artery using sensors fixed on the skin where the pulse is palpable, it does not cause pain and reduces examination time. The coefficients of correlation between the baPWV values obtained from the conventional and present methods were 0.93 (right side) and 0.90 (left side). The results suggest that our system can be used to measure the baPWV without pressure cuffs as accurately as the conventional method.

Refereed Proceeding Papers

- [wenxi-02:2013] Masaki; Tamura Toshiyo; Yoshida Masaki; Ding Shuxue; Chen Wenxi Tang, Zunyi; Sekine. A Novel Method of Nonnegative Sparse Coding for Sparse Representation and Data Clustering. In *uHealthcare 2013*, Yokohama, Japan, September 2013.
- [wenxi-03:2013] Xin; Chen Wenxi Zhou, Xina; Zhu. Long-term Monitoring of “In-bed” and “Out-of-bed” Status of Nursing Home Residents. In *uHealthcare 2013*, Yokohama, Japan, September 2013.
- [wenxi-04:2013] Issei Yanai, Ming Huang, Toshiyo Tamura, Wenxi Chen, Kei-ichiro Kitamura, and Tetsu Nemoto. Experiment System of Noninvasive Deep Body Temperature Thermometer Based on Dual-Heat-Flux Method and its Application on Initial Response Measurement. In *uHealthcare 2013*, Yokohama, Japan, September 2013.
- [wenxi-05:2013] Wenxi Chen Kei-ichiro Kitamura Tetsu Nemoto Ming Huang, Toshiyo Tamura and Shigehiko Kanaya. Geometrical

Improvement of a Noninvasive Core Temperature Thermometer based on Numeric Modeling and Experiment Validation. In *Proceedings of the International Conference on Biomedical Electronics and Devices*, DOI: 10.5220/0004790000230027, pages 23–27, ESEO, Angers, Loire Valley, France, March 2014.

This paper describes the improvement of a transcutaneous core temperature thermometer by modifying the configuration, in terms of height and radius, of the thermometer using the so-called dual-heat-flux (DHF) method. The motivation of these modifications is to decrease the volume of the thermometer so as to reduce the transverse heat flow inside, in other words, to preserve the underlying assumption of the DHF method that heat flows from the inner part of human body through skin onto the thermometer longitudinally. The modification's effect is evaluated by both numeric modeling based on finite element method and experiment. The results of simulations and experiments show that a lower-in-height and larger-in-radius configuration will improve the accuracy of the thermometer. Prototypes of 22.0 mm radius can attain satisfactory accuracy with error less than 0.5 °C when heights are 8.0 mm or less.

[wenxi-06:2013] Wenxi Chen. From Gold Mining to Data Mining Big Data Analytics in Healthcare Application. In *uHealthcare 2013*, page , Yokohama, Japan, September 2013.

165 years ago, California Gold Rush boosted the “Gold Mining” industry, and eventually boomed “Silicon Valley”. Nowadays, we are creating 2.5 quintillion bytes of data every day. Big Data come from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records, mobile phone signals, and personal information. Using state of the art atomic-scale magnetic memory technologies, researchers have demonstrated the possibility to store one bit of data by only 12 atoms which is potentially 100 times denser than today’s hard disk drive technology. Changes in quantity must bring on changes in quality — Big Data are more than simply a matter of size. It paves the way for new and emerging realms, opens the door to a substantial world of opportunities for us to explore, to make our work more agile, our life cozier, and to answer questions that were previously considered beyond our reach. In this talk, a pioneer project, “Challenge to 100 years of age” which was funded by Japanese government and involved more than 600 residents in West Aizu village since 1994, will be reviewed; the latest advancements of Big Data chal-

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lenge in healthcare domain worldwide will be briefly outlined; some of our outcomes in recent studies on system development and data analysis in cooperation with nursing homes and local hospitals will be introduced. These studies utilized multiple vital signs, spanned several years, and covered various subjects, including pregnant women, healthy subjects, chronic patients and elderlies. Data analysis was conducted on different temporal basis, such as daily, weekly, monthly and seasonal. The results reveal long-term dynamics in health condition change of patient and healthy subjects, unveil elder and youngster daily behaviors, contribute to a better understanding of maternal cardiac changes during pregnancy and after delivery, and find insights of more sensitive vital parameters from Big Data analytics. Prospects on future houses as hubs for daily healthcare will be envisioned.

[wenxi-07:2013] Wenxi Chen and Xun Gong. Development of an Automatic System for Persistent Collection of Physiological Information Toward Long-Term Application in Biorhythm Monitoring and Healthcare. In *Proceedings of the International Conference on Biomedical Electronics and Devices*, DOI: 10.5220/0004923902890294, pages 289–294, ESEO, Angers, Loire Valley, France, March 2014.

This study aims to develop an automatic system for persistent collection of physiological information such as pulse rate and SpO₂ in daily environment. The system includes a home-based user terminal and an Internet database server. The user terminal consists of a SpO₂ sensor and a bedside box. The bedside box receives the physiological data from the sensor by Bluetooth connection and relays the data to an Internet-based database server. This system was used to collect the data during daily sleep from a female volunteer at her thirties for a period of more than 15 months. Superior persistence characteristic in daily data collection was confirmed and achieved up to 93.1% of data collection rate comparing with many allied devices or systems that usually ranged about 25% or even less. Average length of menstrual cycles in the female subject was estimated 24.9 days by the cosinor analysis method using the collected data. The result showed satisfactorily accurate with comparing self-recorded length of 27.5 ± 1.3 days. This system is expected to serve as a significant approach for long-term data collection and to obtain more reliable results for the purpose of tracking biorhythm and health condition change.

[zhuxin-03:2013] Koji Fukuda Hiroaki Shimokawa Xin Zhu, Daming Wei. Derived 18-lead ECG in analysis of left-to-right atrial dominant frequency gradient during atrial fibrillation. In *29th Annual Conference of Japan Society for Computerized Electrocardiology*, page NA. Japan Society for Computerized Electrocardiology, 2013.

Background Left-to-right atrial dominant frequency (DF) gradient could be useful to identify the culprit chamber (left or right atrium) for AF maintenance. Previous studies have proved the roles of V1 and V9 leads' f waves in the determination of left-to-right atrial DF gradient. Purpose The aim of this study is to confirm the usefulness of derived 18-lead ECG in noninvasively unmasking left-to-right atrial DF gradient during AF. Method 12-lead ECG and intracardiac electrograms in right atrium (RA), coronary sinus (CS), and right and left upper pulmonary vein were recorded simultaneously for about 11 s from 1 subject with PAF during AF. Then, V3R, V4R, V5R, V7-9 leads were derived from 12-lead ECG based on an information redundancy method. Next, atrial fibrillation activities in surface ECG were obtained in a QT-based method, which does not require QRS and T wave subtractions. Furthermore, intracardiac electrograms were rectified for frequency analysis. Finally, DF was estimated from the peak frequency in 4–9 Hz of each lead's f wave or EGM's FFT. Result DFs obtained from V1 and derived V9 leads are 6.3 and 6.9 Hz, respectively. Average DFs obtained from intracardiac electrograms in RA, CS, and CA were 6.4, 7.0, and 7.0 Hz, respectively. F waves in V1 and derived V9 leads may correspond to right and left atrial fibrillation activities, respectively. Limitation V9 lead was not measured simultaneously and data from more subjects are required for validation. Conclusion DFs obtained from V1 and derived V9 leads may serve as non-invasive indexes to reflect left-to-right atrial dominant frequency gradient, leading to detect the responsible chamber for AF maintenance.

[zhuxin-04:2013] Wenxi Chen Xina Zhou, Xin Zhu. Long-term Monitoring of “In-bed” and “Out-of-bed” Status of Nursing Home Residents. In *Proceedings of uHealthcare 2013*, page NA, 2013.

“Umemory”, a completely unconstrained system is used for long-term monitoring of “in-bed” and “out-of-bed” status in nursing home residents. When a resident lies in a bed, his/her weight can trigger the tactile switch to initiate the DC power supply through a delay controller. Then, the resident's pressure variations due to heart pulsation, respiration, and

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body movement are sensed by a pressure sensor under a pillow or mattress. Then the corresponding digital signal is sent to a database server via Internet and processed by our program to obtain heart rate, respiration rhythm, and body movement epoch during sleep. 1167 days' data from 17 residents in 2 nursing homes were obtained by this system for evaluation. "In-bed" and "out-of-bed" circadian rhythm can be observed for each resident, and the profiles of "in-bed" status can be classified into 5 clusters. As "in-bed" and "out-of-bed" status may be related to the disease severity, daily life style, mental status, and dependency of a resident, our system may provide important evidence for nursing home staff to provide better service for residents and lessen nursing home staff's labour burden.

[zhuxin-05:2013] Yuki Yoshida Daming Wei Motoki Sakai, Xin Zhu. Development of Lead System for the ECG-Derived Respiration Aimed at Detection of Obstructive Sleep Apnea Syndrome. In *Proceedings of International Workshop on Situation Aware Computing at the 9th International Conference on Signal- Image Technology and Internet-Based Systems 2013*, pages 971 – 975, 2013.

Obstructive sleep apnea syndrome is the most common type of sleep apnea, characterized by repetitive pauses in breathing during sleep. Recent studies have investigated screening methods based only on an electrocardiogram (ECG). Generally, in ECG-based screening, the ECG-derived respiration (EDR) is often used, which is caused by the variance in the cardiac electrical axis due to the chest movement associated with the respiration itself. This method might be effective for diagnosing the sleep apnea severity, called the apnea-hypopnea index, which is defined by the duration and occurrence rate of apnea episodes. However, conventional ECG lead systems are not necessarily optimized for this purpose. In this study, nine bipolar electrodes located across the entire ventral thoracic region were devised, based on the conventional lead system, to effectively measure thoracic breathing. To evaluate the most effective electrode placements, two eupneic and three apneic tasks with nine electrodes were conducted, and EDRs were calculated. Then, the respiratory rates were estimated from the EDRs, and the eupnea and apnea groups were classified using features of the EDRs. Consequently, it was found that three electrodes located at the lower thoracic region yielded accurate estimations of the respiratory rate and discrimination rate.

Unrefereed Papers

- [hisada-01:2013] S. Sobue Y. Ogawa N. Hirata H. Demura N. Ito, Y. Hisada. A pilot study based on ALOS/PALSAR for Hydrological monitoring of snowy highland Oze marsh. In *Japan Geoscience Union Meeting 2013*, 2013.
- [hisada-02:2013] S. Sobue Y. Ogawa N. Hirata H. Demura N. Ito, Y. Hisada. A pilot study based on ALOS/PALSAR for Hydrological monitoring of snowy highland marsh, Oze. In *International Symposium on Remote Sensing 2013*, 2013.
- [zhuxin-06:2013] Xin Zhu and Hiroyoshi Furukawa. Study on Heart Rate Variability after Bathing in Hot Spring. In *Proceedings of 2013 Tohoku-Section Joint Convention of Institutes of Electrical and Information Engineers, Japan*, 2013.
- Hot spring has been attracting general interests for health promotion in Japan. However, rare evidence has been found on the effects of hot springs on human beings' health. In this research, we studied the effects of bathing in hot spring on heart rate variability (HRV).

Chapters in Book

- [zhuxin-07:2013] Nemoto Xin Zhu, Wenxi Chen. *Development of an unconstrained monitoring system for the measurement of heart rate, respiration rate, and body movements*, pages 57–65. NTS, October 2013.

Grants

- [hisada-03:2013] Y.Ogawa N.Hirata Y.hisada, H.Demura. Fukushima Prefectural Foundation for Advancement of Science and Education, 2013.
- [zhuxin-08:2013] Xin Zhu and Mahito Noro. Study on the optimum implantation site of implantable cardioverter defibrillators and its clinical usefulness, April 2013.

Academic Activities

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[wenxi-08:2013] Wenxi Chen, Sept 2013.

Invited Lecture: From Gold Mining to Data Mining Big Data Analytics in Healthcare Application uHealthcare 2013, Sept. 12-14, 2013, Yokohama, Japan

Patents

[wenxi-09:2013] Toshiyo; Chen Wenxi Huang, Ming; Tamura. DEEP BODY THERMOMETER, March 2014.

Ph.D and Others Theses

[hisada-04:2013] Tomonari Minakawa. Graduation Thesis: Construction of Heart rate monitoring system with SD card data logger., University of Aizu, 2013.

Thesis Advisor: Y. Hisada

[hisada-05:2013] Masatoshi Igarashi. Graduation Thesis: Effect of snow depth on hydrology of highland marshes -Analysis of PAL-SAR/ALOS data at Kiritappu, Sarobetsu and Oze -, University of Aizu, 2013.

Thesis Advisor: Y. Ogawa

[wenxi-10:2013] Norihiro Kaneko. Estimation of Hypertension Syndrome in Elders by Heart Rate and Respiration Rate during Sleep, Bachelor, March 2014.

[wenxi-11:2013] Hikaru Sasaki. Estimation of User's Mental Status by Sentiment Analysis of Keywords in Facebook Posting, Bachelor, March 2014.

[wenxi-12:2013] Hidenari Takahashi. Development of a Heart Rate Monitor User Interface Using an Android Smartphone with the Intelligent Managers, Bachelor, March 2014.

[wenxi-13:2013] Masayuki Kawai. Characterization of Daily Heart Rate during Sleep Using Umemory System, Bachelor, March 2014.

[wenxi-14:2013] Xina Zhou. Characterization of Sleep Behaviour of Residents in Nursing Homes, Master, September 2013.

[zhuxin-09:2013] Di Yang. Master thesis, Graduate School of Computer Science and Engineering, March 2014.

Atrial fibrillation (AF) is an arrhythmia occurring in daily clinical practice, more in the elderly. As it occurs in 1/2 AF serves as the most popular cardiac arrhythmia and likely to increase in the next 50 years [1]. Therefore, understanding the mechanism of AF's triggering and arrhythmogenic substrates is meaningful for engineers and helpful for medical professionals to develop new drugs. Recently, clinical studies have shown that changes caused by arrhythmia in cardiac electrophysiology may lead to the result of abnormal electrophysiology (electrophysiological reorganization), exacerbating the onset of AF. Understanding of this change in electrophysiology can guide people on the prevention and treatment of AF. In order to confirm the above assumption, our study built a computer model, including electrophysiological changes to describe AF's cellular mechanisms. The typical model of AF consists of atrial cell models with action potentials (AP), and covers an atrial model to simulate the propagation of excitement in the atrium. By comparing the activation propagation, we can get some relevant information about the persistence of AF. To date, many mathematical modeling studies have been reported. Through computer simulation, we may have a deeper understanding on the mechanism of AF to develop a new therapeutic method of atrial fibrillation, and simplify the procedures of developing and testing drugs and medical devices for AF. For antiarrhythmic drugs, we can simulate the ion current of atrial cells by a computer to study the arrhythmogenic substrates of AF. Similarly, we can use the simulation to optimize the catheter ablation position and protocol. Based on previous researches, I realized three simulations related to AF. The first is the reproduction of the excitation conduction process in normal atria. Then I simulated atrial fibrillation by setting the triggering of atrial fibrillation in the vicinity of the tricuspid valve. Finally, I performed the simulation of a cathode ablation procedure, and AF could not be induced again using the stimulation protocol in the second simulation.

Others

[wenxi-15:2013] Wenxi Chen. 坂下厚生総合病院と共同研究, 2013.

[wenxi-16:2013] Wenxi Chen. Lixil Corp. と共同研究, 2013.

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- [wenxi-17:2013] Wenxi Chen. アサヒ電子株式会社と共同研究, 2013.
- [wenxi-18:2013] Wenxi Chen. ネットワーク 2 1 株式会社と共同研究, 2013.
- [wenxi-19:2013] Wenxi Chen. 学会 PC と論文査読 Biomedical Signal Processing & Control BioDevices2014 iCAST2013 EMBC2013 IEEEonITBM IEEE-SMC2014 日本生体医工学など他多数, 2013.
- [wenxi-20:2013] Wenxi Chen. しょうぶ園老人ホームと共同研究 (2 施設), 2013.