Biomedical Information Technology Laboratory

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Professor

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BIT lab is seeking to 1. develop diversified modalities for daily monitoring of physiological information persistently by making use of mathematical means and various physical/chemical principles. 2. perform mathematical simulation and data analysis to reveal statistical links between the incidence of various chronic diseases and longterm dynamics of health condition. 3. 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. 4. foster a new discipline "Metrology of Health" or "Healthology".

In AY 2012, Prof. Chen's research activities continued focusing on the ICT-based healthcare domain to pursue a total solution for daily monitoring of various physiological information and lifelong healthcare. Prof. Chen conducted several projects. These studies headed towards a system development, including a series of instrumentation for seamless and persistent monitoring of vital signs without disturbing subjects in daily life environment, and an Internet-based infrastructure. 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 aims to collect elderly data and to assess the system performance through field trial. A cooperative study with Bange Welfare General Hospital was to collect clinical data from patients suffering from chronic diseases, and to evaluate the therapeutic effect during treatment. Cooperative studies with Lixil Corp. and Asahi Denshi Corp. were ongoing and will develop the tie further in the coming years. Various algorithms for Big Data analytics in biomedical information application were developed to objectively characterize the subject's health dynamics.

Prof. Zhu's researches are focused on biomedical signal processing and cardiac computer simulation. A new algorithm based on sinusoidal approximation has been developed for the time-frequency analysis of ECG atrial fibrillation waves through collaboration with Tohoku University Hospital and the support from JSPS Grant-in-aid basic research fund. The other research on the computer simulation of implanted cardioverter defibrillator's defibrillation was conducted through collaboration with Cardiology Division, Ohashi Hospital, Toho University. Preliminary research result has proved the efficiency of a new ICD implantation method by implanting ICD generator in left fossa instead of the traditional right precordial region. 1 journal and several conference authored and co-authored papers were published in the two fields.

Summary of Achievement

Refereed Journal Papers

Refereed Proceeding Papers

[wenxi-02:2012] Ming Huang Xina Zhou, Xin Zhu and Wenxi Chen. Automatic monitoring of sleep behaviour in nursing home residents. In *Proceedings of the IASTED International Conference Biomedical Engineering (BioMed 2013)*, pages 347–352, Innsbruck, Austria, Feb. 2013.

In this paper, we propose a completely unconstrained method for automatic monitoring of sleep behaviour and health status in nursing home residents using an Internet-based automatic sleep monitoring system mainly composed of a pressure sensor and a data server. When a nursing home resident lies in bed, his/her pressure variations due to heart pulsation, respiration, and body movement are sensed by a pressure sensor under a pillow or mattress. Then the corresponding digital signal is sent to a data server via Internet and processed by a background program to obtain heart rate, respiration rhythm, and body movement information in bed. 231 whole days' data from 5 subjects in a nursing home were obtained by this system for evaluation. Through comparing with records provided by nursing home staff, we found our system can accurately and reliably estimate heart rate, respiration rhythm, and body movement during sleep for the analysis of circadian rhythm and sleep quality. It is concluded that our method may serve as an effective and convenient tool for automatic monitoring nursing home residents' casual lifestyle, circadian rhythm, and health status. The introduction of this system may also lessen the burden of nursing home staff and help to realize personal specific healthcare service.

[wenxi-03:2012] Xin Zhu Kei-ichiro Kitamura Wenxi Chen, Ming Huang and Tetsu Nemoto. Beat-by-Beat Monitoring of Systolic Blood Pressure based on an ASIC and a Mobile Phone for Ambulatory Application. In *Proceedings of the International Conference on Biomedical Electronics and Devices (BioDevices2013)*, DOI: 10.5220/0004192600100013, pages 10–13, Barcelona, Spain, Feb. 2013.

This paper describes an ambulatory monitor for beat-by-beat monitoring of systolic blood pressure (SBP) based on an ASIC chip and a mobile phone. The ASIC is able to measure electrocardiogram (ECG), photoelectric plethysmogram (PPG), and has a peripheral interface to control an air pump and valve

for inflating and deflating a sphygmomanometer cuff in conventional blood pressure measurement. Algorithms for signal processing, characteristic point detection and SBP estimation are implemented on a mobile phone. Pulse arrival time (PAT) is derived from the apex of QRS complex to the maximum slope of PPG, and is used to estimate a rapid change component in SBP beat-by-beat. An oscillometric sphygmomanometer with a cuff is used to determine SBP intermittently for calibration purpose. Data communication between a mobile phone and the ambulatory monitor is conducted via a Bluetooth wireless connection. Performance of the prototype is examined by data from five healthy college students. The results show that 65.9relative error, 96.6study aiming at integrating an innovative sphygmomanometry into a mobile phone for continuous blood pressure monitoring. We expect to find potential applications in ambulatory monitoring and daily healthcare.

[wenxi-04:2012] Wenxi Chen Daming Wei Yuki Yoshida, Xin Zhu. Evaluation of synthesized electrocardiogram on additional leads based on clinical data. In *Proc. of 2012 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems*, DOI: 10.1109/VECIMS.2012.6273186, pages 65 – 68, Tianjin, China, July 2012.

Additional lead electrocardiogram (ECG) has been proved to be useful in the diagnosis of acute myocardial infarction. However, the additional leads are not routinely employed due to limits of traditional electrocardiograph systems, and inconvenience and strains on patients during measurement. Our research team has developed a method to synthesize a "virtual" ECG on an additional lead based on computer simulation of heart. The synthesized additional leads ECG makes it possible that more detailed information can be obtained conveniently by using existing electrocardiograph. In this research, ECGs on standard 12 leads and additional leads are measured from 302 subjects. 150 subjects' data are randomly selected and used as learning data to estimate the transfer coefficient for deriving three right ventricular leads V3R, V4R, and V5R, and three posterior chest leads V7, V8, and V9 based on the method proposed by us. Then, the other subjects' ECG on additional leads are synthesized from the 12 lead system and compared with the actually measured counterparts. Difference of Q wave, R wave, and ST segment, and the correlation of averaged ECG are defined and estimated from the synthesized and measured data as evaluation indexes. Evaluation results demonstrate that "virtual" additional leads can be derived from 12 standard leads with a high

accuracy qualified for clinical diagnosis of cardiac diseases.

[wenxi-05:2012] Kei-ichiro Kitamura Tetsu Nemoto Ying Chen, Wenxi Chen. Sleep Quality Evaluation by Using Pulse Rate during Sleep. In *Proc. of the 51st Annual Conference of Japanese Society for Medical and Biological Engineering*, pages 1–2, Fukuoka, Japan, May 2012.

In this study, we applied a sleep monitoring system to a local nursing home and evaluated sleep qualities by using pulse rate (PR). One 77-year-old female resident diagnosed as Alzheimer's disease and hypertension was involved. PR was recorded during daily sleep and its profile pattern was compared between good-sleep and troubled-sleep nights. Histogram was used to present the distribution of daily PR data. Meanwhile, nursing record of the subject was taken as a reference. In results, we found that PR profile quite differed in good sleeps and troubled sleeps. The former has lower level of PR with mild fluctuations and showed a relatively symmetrical leptokurtic distribution. Meanwhile, the latter had an increased PR level with wild fluctuation and presented a wide based, platykurtic negative skewed distribution, unimodal or bimodal. We hope this approach can serve as a supplementary mean to the nursing staffs and be helpful in daily health management.

[wenxi-06:2012] Kei-ichiro Kitamura Tetsu Nemoto Ming Huang, Wenxi Chen. The inverse heat transfer problem of an anatomy-based two-dimensional model for measurement of deep body temperature in human abdomen. In *Proc. of the 51st Annual Conference of Japanese Society for Medical and Biological Engineering*, pages 1–2, Fukuoka, Japan, May 2012.

In order to further investigate the noninvasive estimation of deep body temperature inside human abdomen using inverse method, this paper proposes a two-dimensional model of human abdomen based on morphological anatomy and functional anatomy. This model is segmented into three layers (skin layer, muscle layer and surrounding tissue layer) from external to internal along with six major organs (stomach, liver, left and right kidney, spleen and spine) inside abdominal cavity. The physical properties of the three-layer are distinctive from each other and the heat effects of the blood perfusion and metabolism are included in the muscle and skin layers. In the light of the characteristic of the physiological structure of the six organs, five of them are assumed to be isothermal, while liver is further segmented into five parts according to its functional anatomy. The accuracies of the estimations for these ten zones de-

pend primarily on the locations of the target zones. Nine zones ' temperature values can be estimated accurately.

[zhuxin-02:2012] Xin Zhu, Daming Wei, Koji Fukuda, and Hiroaki Shimokawa. A Simple Atrial Fibrillatory Wave Reconstruction Method for Frequency Analysis of Atrial Fibrillation using Single-Lead ECG. In A.R. Boccaccini, editor, *Proceeding (791) Biomedical Engineering - 2013*, pages 791–016. ISTAED, ACTA Press, 2 2013.

A cosine-function-based approximation method is proposed to reconstruct atrial fibrillatory wave in QRST intervals for estimating dominant frequency of atrial fibrillation (AF) using single-lead ECG. It is hypothesized that atrial fibrillatory waves in two adjacent QRST intervals can be approached by a cosine function and direct component. As harmonics of dominant frequency are neglected, the determination of harmonics ' number and Tikhonov regularization are avoided compared with previous methods. Initially, we build a learning data set composed of at most 3 TQ intervals neighboring to the two QRST intervals. Next, the optimum frequency of cosine is determined in an enumeration way using the learning data set, and the corresponding amplitude, phase, and direct component are estimated in a least square method. Finally, the atrial fibrillatory waves in the two adjacent QRST intervals are calculated based on the cosine function and direct component. This method is simple and convenient, and the atrial fibrillatory waves in ectopic QRST intervals can also be easily estimated. Through evaluation with artificial and clinical AF ECG, we proved that frequency analysis of atrial fibrillation based on this method can obtain a dominant frequency profile with less standard deviation than that based on ABS method.

[zhuxin-03:2012] Xina Zhou, Xin Zhu, Ming Huang, and Wenxi Chen. Automatic Monitoring of Sleep Behaviour in Nursing Home Residents. In A.R. Boccaccini, editor, *Proceeding (791) Biomedical Engineering - 2013*, pages 791–054. ISTAED, ACTA Press, 2 2013.

In this paper, we propose a completely unconstrained method for automatic monitoring of sleep behaviour and health status in nursing home residents using an Internet-based automatic sleep monitoring system mainly composed of a pressure sensor and a data server. When a nursing home resident lies in bed, his/her pressure variations due to heart pulsation, respiration, and body movement are sensed by a pressure sensor under a pillow or mattress. Then the corresponding digital signal is sent to a data server via Internet and processed by a background program to obtain heart rate, respiration

rhythm, and body movement information in bed. 231 whole days ' data from 5 subjects in a nursing home were obtained by this system for evaluation. Through comparing with records provided by nursing home staff, we found our system can accurately and reliably estimate heart rate, respiration rhythm, and body movement during sleep for the analysis of circadian rhythm and sleep quality. It is concluded that our method may serve as an effective and convenient tool for automatic monitoring nursing home residents ' s casual lifestyle, circadian rhythm, and health status. The introduction of this system may also lessen the burden of nursing home staff and help to realize personal specific healthcare service.

[zhuxin-04:2012] Xin Zhu, Osamu Okazaki, , and Daming Wei. 心臓モデルによる頻脈誘発及び抗頻ペーシングのシミュレーションによる検討. In 第 *29* 回日本心電学会学術集会論文集, page 85. 日本心電学会, 日本心電学会, 10 2012.

目的：不整脈の診療において、臨床電気生理学検査は頻脈誘発や抗頻ペーシングを用い応用されている。しかし、動物実験やコストの制限などでそれに関する基礎研究や教育には未だ問題が残る。そこで本研究は、心臓モデルを用い不整脈の誘発及び停止効果を検討するためコンピューター上でシミュレーションを行い、臨床上の疑問を考察することを目的とする。 方法及び結果：Wei-Harumiモデルを導入し、WPW 症候群（type A）モデルを作成した。各心筋細胞の活動電位、不応期及び伝導速度回復などを設定し、HRA、LVにての期外刺激、漸増刺激を用いて、上室性頻脈誘発のシミュレーションを行った。このモデルでは、他の刺激より HRA における期外刺激及び漸増性心房ペーシングでは、比較的に長い周期（340ms）でも上室性頻脈を誘発することが可能であった。また、期外刺激、burst、rampなどを用い抗頻脈ペーシングでの頻脈停止効果も確認できた。
結論：心臓シミュレーションは倫理、動物実験などの問題を回避し、臨床不整脈の問題点について、心臓興奮活動現象を再現可能とした。これにより、不整脈発生機序や停止効果を確認することで治療への応用性を示すことが期待される。

[zhuxin-05:2012] Jie Li Weimin Xu Daming Wei Xin Zhu Wenfeng Shen, Liang Wang. Load-prediction Parallelization for Computer Simulation of Electrocardiogram based on GPU. In *Embedded Multicore Socs (MC-SoC), 2012 IEEE 6th International Symposium on*, pages 155–158. the University of Aizu, IEEE, 9 2012.

This paper introduces a parallel algorithm using GPU for computer simulation of Electrocardiogram (ECG) based on a 3-dimensional (3D) whole-heart

model. The computer heart model includes approximately 50,000 discrete elements (cell models) inside a torso model represented by 344 nodal points with 684 triangular meshes. Since computational burden for computer simulation of ECGs is considerably heavy, we employ GPU to accelerate the speed of calculation. However, GPU is based on SIMD structure which is unsuited for branch structure, so that the computing capabilities of GPU are limited by the branch of program. In order to solve this problem, we present a GPU-based algorithm which concentrates on eliminating branches in computation and optimizing the calculation of electric potentials through the way of load-prediction. The new parallel algorithm accelerates the speed of calculation of ECGs to 6.18 times compared with the former algorithm. This study demonstrates an effective algorithm based on GPU for parallel computing in biomedical simulation study.

[zhuxin-06:2012] Wenxi Chen Daming Wei Yuki Yoshida, Xin Zhu. Evaluation of synthesized electrocardiogram on additional leads based on clinical data. In *Virtual Environments Human-Computer Interfaces and Measurement Systems (VECIMS), 2012 IEEE International Conference on*, pages 65–68. Tianjin University, IEEE, 7 2012.

Additional lead electrocardiogram (ECG) has been proved to be useful in the diagnosis of acute myocardial infarction. However, the additional leads are not routinely employed due to limits of traditional electrocardiograph systems, and inconvenience and strains on patients during measurement. Our research team has developed a method to synthesize a "virtual" ECG on an additional lead based on computer simulation of heart. The synthesized additional leads ECG makes it possible that more detailed information can be obtained conveniently by using existing electrocardiograph. In this research, ECGs on standard 12 leads and additional leads are measured from 302 subjects. 150 subjects' data are randomly selected and used as learning data to estimate the transfer coefficient for deriving three right ventricular leads V3R, V4R, and V5R, and three posterior chest leads V7, V8, and V9 based on the method proposed by us. Then, the other subjects' ECG on additional leads are synthesized from the 12 lead system and compared with the actually measured counterparts. Difference of Q wave, R wave, and ST segment, and the correlation of averaged ECG are defined and estimated from the synthesized and measured data as evaluation indexes. Evaluation results demonstrate that "virtual" additional leads can be derived from 12 standard leads with a high accuracy qualified for clinical diagnosis of cardiac diseases.

Unrefereed Papers

[wenxi-07:2012] Wenxi Chen. Invited talk Lifelong Healthcare: Seamless Monitoring from Womb to Tomb. In *The 10th Annual International Conference on Ubiquitous Healthcare (u-Healthcare2012)*, GyeongJu, KOREA, Oct. 2012.

> Pursuing a healthier and longer life is neither a new desire nor a modish topic, and has been an ambition of human beings since ancient times. Lifelong healthcare is now a global challenge and attracting attention worldwide. More and more professional communities, research institutions, and industrial sectors have been placing high priority on development of special devices and relevant infrastructures for personalized healthcare. However, an investigation from the WHO reported that most current healthcare paradigms still have common problems such as (a) the difference between acute and chronic care is not sufficiently emphasized; (b) people are rarely supported by a simple means of involving themselves in daily self-management, and (c) people are seldom provided with a persistent care plan over long-term period. In this lecture, the historical development and the latest achievements of healthcare-related issues worldwide will be briefly reviewed. A government-funded project, "Challenge to 100 years of age" which involved more than 600 residents in West Aizu village since 1994, will be outlined. Afterwards I will introduce some outcomes of our recent researches on system development in cooperation with nursing homes and local hospitals. These studies include pregnant women, healthy subjects and patients with chronic diseases. The outcomes reveal long-term dynamics in health condition of patient and healthy subjects, unveil elder and youngster life behaviors, and contribute to a better understanding of maternal cardiac changes during pregnancy and after delivery. The real field operation over two years validates the feasibility of the system in practical application. As a result, an integrative strategy to tackle above challenging problems is proposed to meet today's pressing needs in healthcare domain. Continuous efforts will make it possible to cover care cycles from womb to tomb in the future.

Grants

[zhuxin-07:2012] Daming Wei, Koji Fukuda, Xin Zhu, and Hiroaki Shimokawa. Study on the utilization of derived 18-lead ECG in the diagnosis of atrial fibrillation, 4 2012-2014.

Xin Zhu works as a research collaborator in this research.

Patents

[wenxi-08:2012] Masumi; Togawa Tatsuo Chen, Wenxi; Kitazawa. MENSTRUAL CYCLE ESTIMATION DEVICE AND METHOD, Oct. 2012.

Ph.D and Others Theses

[wenxi-09:2012] Ying Chen. Analysis of Longterm Pulse Rate Variability and Its Applications in Personal Health Care, Ph.D., Sept. 2012.

[wenxi-10:2012] Ming Huang. Finite Element Method and Human Abdominal Model Based Study on Two-Dimensional Estimation of Deep Body Temperature, Ph.D., Sept. 2012.

[wenxi-11:2012] Yumi Sato. Development of a Temperature Control System of Real Geometrical Models for a Deep Body Temperature Study, Bachelor, March 2013.

[wenxi-12:2012] Kentarou Yamamoto. Characterization of Body Movement During Sleep Using Umemory System, Bachelor, March 2013.

[wenxi-13:2012] Takuma Yabe. Effects of Ambient Sound on Pulse and Respiration Rates during Sleep, Bachelor, March 2013.

[wenxi-14:2012] Ryo Yamaguchi. Analysis of Diurnal Activity of Elderly Residents in Nursing Home, Bachelor, March 2013.

[wenxi-15:2012] Tetsuya Abe. Selection of Electrode Placements and Frequency Bands for EEG-based Calculation Capability estimation: Optimization Using Generic Algorithm and support Vector Machine, Master, March 2013.

Others

[wenxi-16:2012] Wenxi Chen. Lifelong Healthcare - Seamless Monitoring from Womb to Tomb. WIP seminar, December 2012.

Summary of Achievement

[wenxi-17:2012] Wenxi Chen. Lifelong Healthcare: Seamless Monitoring from Womb to Tomb, Sept. 2012.

Invited lectures in China to Jinan University, Guangzhou Shanghai University, Shanghai Shanghai Jiaotong University, Shanghai Zhejiang University, Hangzhou