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An ISHNE based Long-term ECG-HRV Data Format

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Abstract. This paper proposes a common data format for the long-term ECG related biosignals, *i.e.* ECG waveform, annotated RRI intervals and IoT device data aiming at establishing the standardized ECG lifelong data logging scheme. Based on the Holter standard output file format specified by International Society for Holter and Noninvasive Electrocardiology (ISHNE), the efficient data representation method for ECG related data is proposed. The proposed format will facilitate the open development of ubiquitous health care system with emerging IoT technology.

Keywords: Standard ECG Data Format, Heart Rate Variability, ISHNE, Lifelong data Logging, Ubiquitous Health Care

1. Introduction

Ubiquitous health care system development has been of great interest to keep peoples' wellness [Li *et al.*, 2017; Islam *et al.*, 2015; Mora *et al.*, 2017]. Continuous long-term monitoring of heart rate variability (HRV) and even the electrocardiogram (ECG) waveform are getting to be realized and could be utilized for the advanced ubiquitous health care. In the for-discussion section of the latest issue of Methods of Information in Medicine [Yana, 2016; Deserno and Marx, 2016], the vision of Computational Electrocardiography (CECG) has been discussed where continuous ECG data are acquired, stored and processed for the timely feedback to realize the advanced health care practice. Emerging technologies such as IoT or the cloud information systems would be the key to realize this CECG vision. The common data format of ECG and annotated HRV data will facilitate such system development. The proposed data format extends the Holter standard output file format (ISHNE) [Badilini, 2006] and the Telemetric and Holter ECG Warehouse (THEW) format [Rochester University, 2012] to include both ECG waveform, annotated HRV data and data from IoT devices.

2. Proposed ECG-HRV Integrated Data Format

The proposed format consists of four parts, *i.e.* the header, annotated RRI data block, ECG waveform data block and IoT data block as shown in Figure 1.

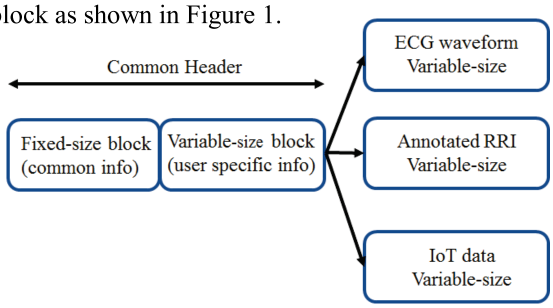

Figure 1. Proposed long-term ECG-HRV data format structure
(*The format aimes at enabling to store lifelong ECG-HRV and IoT data*)

2.1. Header Format

The header is divided into two blocks, *i.e.* the fixed and variable size parameter blocks. Fixed block includes common information of the subject (subjects' age, sex, etc.) and technical info such as data size/offset. The variable-size block is for some additional information for the user. Table 1 and 2 show examples of fixed and variable size parameter blocks.

Table 1. Fixed-size block

Description	*Data Type*	*Size [Bytes]*
Size of variable length block	integer	4
Size of annotated RRI data block	integer	4
Offset of annotated RRI data block	integer	4
ID	character	20
Sex (0: unknown, 1: male, 2: female)	integer	1
Age (-1: unknown)	Signed integer	2
Start time (day, month, year, hour[0-23], min, sec, msec	integer	14
Sampling rate	integer	2
Type of record (analog or digital)	character	80
Copyright	character	80

Table 2. Variable-size block (an Example)

Description	*Data Type*	*Size [Bytes]*
Size of ECG data block	integer	4
Offset of ECG data block	integer	4
Number of stored Leads	integer	2
Lead specification	integer	24
Lead quality	integer	24
Amplitude resolution	integer	24
First Name (encrypted)	character	40
Last Name (encrypted)	character	40
Country (JPN etc)	character	10
temperature (℃)	signed integer	1
relative humidity (%)	integer	1
⋮	⋮	⋮

2.2 Annotated RRIs:

The annotated RR interval data unit consists of 4-bit annotation and 12-bit RR intervals for each beat. To avoid the accumulation of truncated errors, the exact *R* wave occurring times are recorded first preceding to calculate RR intervals. Overflow flags are introduced to avoid the interval truncation errors. The flag is included in the 4-bit annotation. Beat to beat annotation include NLB: Normal beat, PVC: Premature ventricular contraction, SPB: Supraventricular premature or ectopic beat, ART: artefact to be excluded from the analysis, OVF: Overflow flag.

Table 3. Coded beat to beat annotation

Description	*Annotation*	*code*
Normal beat	NLB	1
Premature ventricular contraction	PVC	4
Supraventricular premature or ectopic beat	SPB	2
⋮	⋮	⋮
artefact to be excluded from the analysis	ART	14
Overflow flag	OVF	15

Table 3 shows the 4 bit annotation part for each beat. Possible annotations including control flags such as overflow indicator OVF are coded and stored preceding to the RRI data. 12 bits, allocated to RRI data, can store intervals less than 8 seconds which is sufficient for almost all cases. However, the artefacts or loose/missing electrode contact may cuase an unexpectedly long RRI intervals. The typical case is the data segment annoted as ART occurs after the sequence of OVF data segments as shown in Fig. 2. Even in such a case, The subsequent R-wave occurring times will be correctly preserved.

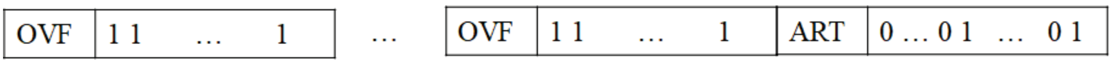

Figure 2. A typical case where the RRI overflow occurs
(*Each segment has 4-bit annotation followed by the 12-bit RRI interval in milli-seconds.*)

2.3 ECG waveform recording format:
ECG wave forms are to be stored by the initial value and subsequent difference signals for each channel. The full-resolution amplitude sequence has to be temporally stored prior to calculate the difference sequence to avoid the accumulation of truncated errors. Initial data value is stored by 16bit signed integer. 7bit signed integer is used for the subsequent difference signal data. LSB is used for the overflow flag with which original data will be guaranteed to be restored.

2.4 IoT device data attachment:
Heart rate wearable sensors are getting to be available in consumer health care device market. Although the recoding accuracy is not sufficient for clinical use at this time, it may be useful for the daily health check. Figure 3 shows a typical example of IoT data extracted by the wrist device (*Fitbit Charge II, Fitbit Inc.*). Average heart rate and the number of steps in every 1-minute interval can be retrieved from the cloud database.

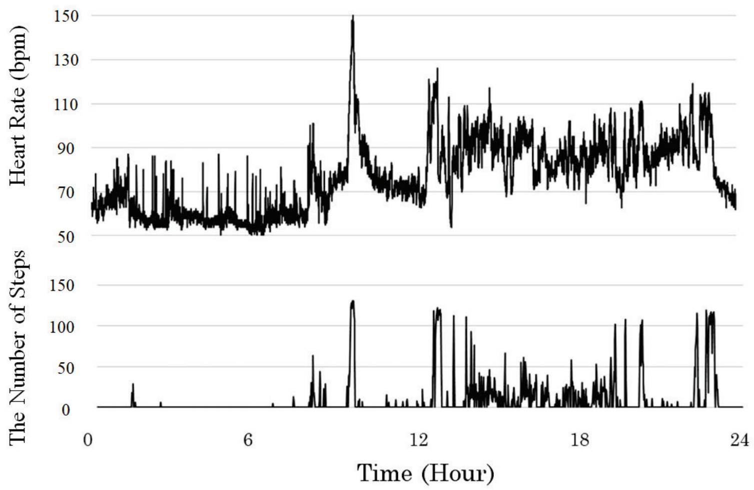

Figure 3. An example of health care related IoT data continuously stored on a cloud
(*Average heart rate and number of steps are recorded in every one-minute interval*)

Since data obtained by IoT devices are varied, the data format has to be device dependent at this time. Here we will propose, as an example, to attach a typical data continuously monitored by the IoT device. In the case where the device records *n*-different data in every minute *e.g.* the average heart rate, the number of steps, all raw data are suggested to store sequentially as shown in Figure 4. Even the lifelong data needs 1 Giga-byte of storage if we assume the continuous record of 10 sensor outputs with the data resolution of 16bit for 100 years.

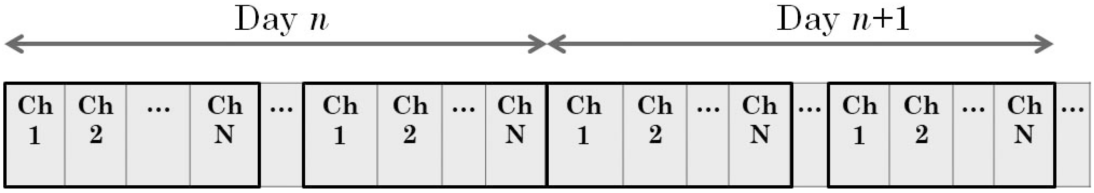

Figure 4. IoT data format

(*Uncompressed N-channel raw IoT data are continuously attached to the ECG-HRV data*)

3. Discussion

According to the proposed format, typical data size for the annotated RRI data is found to be approximately 200KB based on 24-hour ECG data assuming the mean heart rate is 70 beats/min. Hence, the data size is not at all the problem for even the lifelong data logging. Because of the rapid development of wearable/IoT technology, long-term ECG data recording over 24 hours are getting to be available. Wearable long-term ECG recording has been studied [Pantelopoulos and Bourbakis, 2010; Arnold and Layton, 2015]. A FDA approved 2-week ECG recording device has been already available for clinical use [Deserno and Marx, 2016; Nemati, 2012]. The long-term annotated RRI data monitoring will soon be a common practice. For this end, the development of accurate automatic annotation algorithm development is indispensable [Christov, I. *et al.*, 2006]. ECG raw waveform data cannot be kept for such a long time as annotated RRI data. Hence it needs to be kept in a FIFO storage. The introduction of more sophisticated data compression for ECG waveform data may enable its lifelong tracking. IoT health care monitoring technology has been flourishing and it may not be a right time to specify the detailed standardized format. However, it may be useful to attach tentative well thought out common IoT data format based to the well defined data format for the ECG waveform and annotated RRI data.

4. Conclusion

This paper proposes an integrate data format of ECG related long-term bio-signals aiming at establishing its common standard. The benefit of having such common data format is to facilitate the open research/system development collaboration. Open source software development has been a major trend in the general data management system development [Scacchi *et al.*, 2006]. Successful examples in the medical and health care fields are MIT-BIH arrhythmia database [Moody and Mark, 2001] and THEW project [Rochester University, 2012]. Developing a standardized data format including IoT sensor signals, discussed in this article, will be useful for the ubiquitous health care system development based on the continuous health data acquisition/monitoring using emerging IoT sensor technology. Open discussion to elaborate the data format, namely the efficient coding algorithm implementation, will be expected to make the format be a common standard.

References

Arnold RJG and Layton A. Cost analysis and clinical outcomes of ambulatory care monitoring in medicare patients: describing the diagnostic odyssey. *Journal of health care economics and outcomes research*, 2(2): 161-169, 2015.

Badilini F. The ISHNE Holter standard output file format. *Annals of Noninvasive Electrocardiology*, 3(3): 263-266, 2006.

Christov I, Gomez-Herrero G, Krasteva V, Jekova I, Gotchev A and Egiazarian K. Comparative study of morphological and time-frequeny ECG descriptors for heatbeat classificaiotn. *Medial Engineering &Physics*, 28(9): 876-887, 2006.

Deserno TM and Marx N. Computational electrocardiography: revisiting Holter ECG monitoring. *Methods of information n Medicine*. 55(4): 305-311 , 2016.

International Organization for Standardization. ISO 22077-1:2015 health informatics- Medical waveform format part 1: encoding rules, 2015.

Islam SMR, Kwak D, Kabir MDH, Hossain M and Kwak K-S. The Internet of things for health care: a comprehensive survey. *IEEE Access*, 3: 678-708, 2015.

Li C, Hu X and Zhang L. The IoT-based heart disease monitoring system for pervasive healthcare service. *Procedia Computer Science*, 112: 2328-2334, 2017.

Moody GB and Mark RG. The impact of the MIT-BIH arrhythmia database. *IEEE Engineering in Medicine and Biology Magazine*, 20(3): 45-50, 2001.

Mora H, Gil D, Terol RM, Azorin J and Szymanski J. An IoT-based computational framework for healthcare monitorning in mobile environments. *Sensors*, 17: 1-25, 2017.

Nemati E, Deen J, and Mondal T. A wireless wearable ECG sensor for long-term applications. *IEEE Communication Magazine*, 50(1): 36-43, 2012.

Pantelopoulos A and Bourbakis NG. A survey on wearable sensor-based systems for health monitoring and prognosis. *IEEE Trans. Systems Man and Cybernetics Part C*, 40(1): 1-11, 2010.

Reyes BA, Posada-Quintero HF, Bales JR, Clement AL, Pins GD, Swiston A, Riistama J, Florian JP, Shykoff B, Qin M and Chon KH. Novel electrodes for underwater ECG monitoring. *IEEE Transactions on Biomedical Engineering*, 61(6): 1863-1876, 2014.

Rochester University Telemetric and Holter ECG Warehouse. THEW data format: http://thew-project.org/THEW FileFormat.htm, 2012.

Scacchi W, Fellor J, Fitzgerald B, Hissam S and Lakhani K. Understanding free/open source software development processes. *Software Process Improvement and Practice*, 11: 95–105, 2006.

Yana K. Editorial for computational electrocardiography: revisiting Holter ECG monitoring. *Methods of Information in Medicine*, 55(4): 303-304, 2016.