Fatigue Detection System using Enhanced So and Chan Method

Chia-Yu Wang, Robert Chen-Hao Chang, Chih-Hung Lin, and Sih-Hao Su
National Chung Hsing University, Taichung, Taiwan

***Abstract*—The key objective of the ECG monitoring system is QRS complex detection. An Enhanced So and Chan Method is proposed in this paper to improve the So and Chan method. It can effectively reduce the fail detection rate. Compared to the original So and Chan method, the accuracy increases from 94.61% to 99.16%. A FPGA board is used to verify our algorithm. Then we take the RRI data into PC for power spectral density analysis to get LF / HF. The results can be used to determine the driver's state.**

I. Introduction

Fatigue driving might cause serious traffic accidents [1]. The common fatigue detection systems use nod or blink frequency to make judgment [2]-[5]. However, the above methods use the information that the driver has already entered fatigue state. Hence, it cannot early warn the drivers. In this paper, we use heart rate variability analysis (HRVA) in the frequency domain to detect whether the driver enters fatigue state or not.

Many QRS complex detection algorithms have been proposed. In 1997, So and Chan proposed an R-peak detection algorithm for real-time ECG monitoring called “So and Chan” [6], which is based on dynamic threshold algorithm and maximum slope detection of digital ECG for the identification of QRS onset, so as to find out the absolution position of the R-peak.

This paper is organized as follows. The proposed fatigue detection system is described in Section II. In Section III, the implementation results are given. Section IV concludes this paper.

II. The Proposed System

The proposed fatigue detection system is shown in Figure 1. R waves of electrocardiogram (ECG) signals are detected using the Enhanced So and Chan method. After the R-R interval (RRI) is counted, signal preprocessing and FFT are conducted. Subsequently, power spectrum density (PSD) data are caculated to get LF / HF.

A. Enhanced So and Chan

The R wave detection method is implemented using the algorithm of Enhanced So and Chan. Data acquired in the time domanin are prosessed using slope caculation, as follows:

$$slope(n) = -2X(n-2) - X(n-1) + X(n+1) + 2X(n+2) \quad (1)$$

The largest slope is then identified and the threshold is determined to detect the QRS complex wave. R wave position is detected after then. This method is based on the slope and almost requires no baseline shifting. The slope of every signal $X(n)$ is represented by $slope(n)$.

Figure 2 is the flow chart of the Enhanced So and Chan method. There are three advantages of this algorithm:

- Applicable on mobile and real-time ECG monitoring systems.
- Reduced computing required, and easy to implement on a chip for real-time detection.
- Reduces false detection caused by RSR’ (notched R wave) [7] or large T wave.

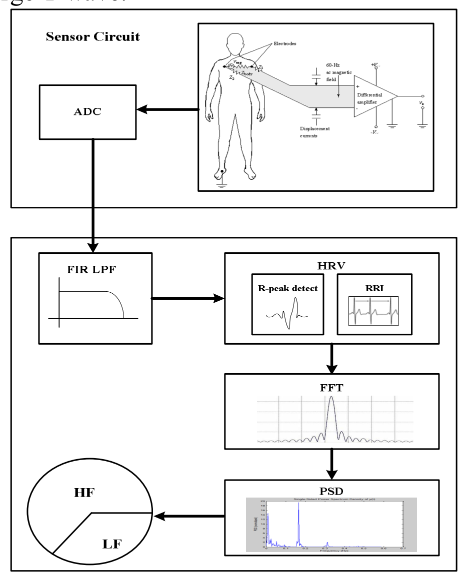

Fig 1. Block diagram of the proposed system

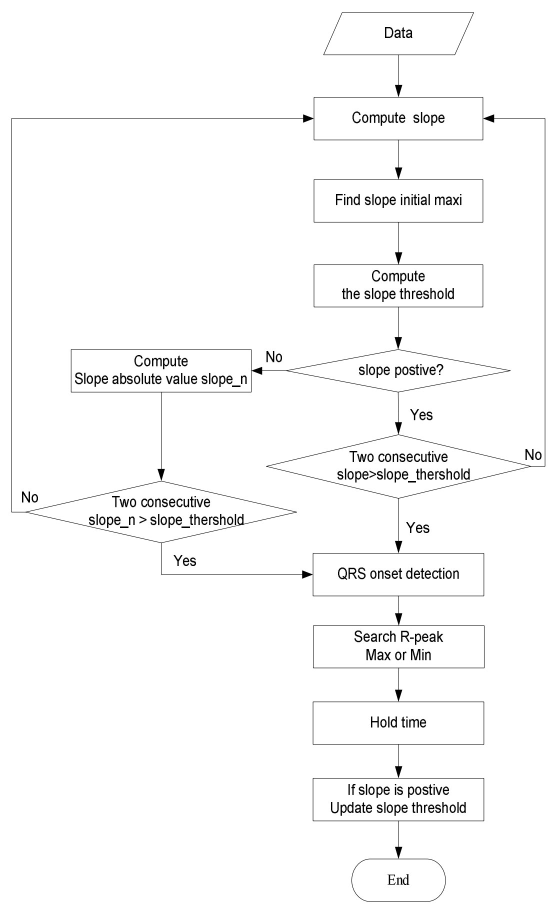

Fig 2. Enhanced So and Chan Method

B. Preprocessing Signal

The resampling method adopted in this study is linear interpolation, and the sample rate is 2 Hz. Because the Gibbs phenomenon occurs in spectrum conversation and causes serious aliasing in high and low frequency signals [8], FFT errors must be suppressed to minimize them in the heart rate variability (HRV) analysis, which focuses on low frequency [9]. Although the Hann window function is not as efficient as the Hamming window function in supressing errors, programming is easier.

C. FFT & PSD

Radix-2 decimation-in-time FFT (DIT-FFT) with 512 points is implemented in the proposed structure. For a frequency of heart rate below 1 Hz, we separate it to ultra low frequency (ULF), which has a frequency range of <0.003 Hz; very low frequency (VLF) from 0.003 to 0.04 Hz, which represents the temperature regulation system; low frequency (LF) from 0.04 to 0.15 Hz, which represents sympathetic activity or sympathetic and parasympathetic simultaneously controlled indicators; and high frequency (HF) from 0.15 to 0.4 Hz, which is associated with breathing and parasympathetic system activity [10-12].

PSD analysis can be performed to obtain the LF/HF ratio. Because LF represents parasympathetic and HF represents sympathetic, when LF is larger than HF, drivers are in a normal or excited state; by contrast, when LF is smaller than HF, drivers are in a fatigued or over-relaxed state.

III. Implementation Results

Table I shows a comparison between the performance of the QRS complex detection algorithm and other references. The table is divided into two parts: one is a comparison between the first 24 records of MIT-BIH database, and the other is a comparison between the entire 48 records. As shown in Table I, R-peak detection by using the Enhanced So and Chan method can substantially reduce the error rate.

Table I QRS detection algorithm comparison

QRS Detection Algorithm	R-peak False Detection rate (%)
	24 Record / 48 Record
Tompkins[13]	NA / 0.68
Wavelet – Haar[14]	2.54 / NA
Wavelet – Db3[14]	1.72 / NA
Wavelet – Quardratic[14]	2.32 / NA
Wavelet – Cubic B-spline[14]	0.75 / NA
Correlation Integral Method[15]	0.85 / NA
So and Chan[6]	4.07 / 5.47
Modified So and Chan[16]	0.63 / 1.11
Enhanced So and Chan	0.22 / 0.84

IV. Conclusion

This fatigue detection system detects the peak of the QRS complex on the basis of the Enhanced So and Chan method. The simulation results show that the average accuracies of the QRS complex detection are 99.16%. This system uses HRVA in the frequency domain to make judgment of the drivers. We can warn the drivers earlier by this method and it's a good help to prevent traffic accident.

References

[1] Kingman P. Strohl, and et al., "Drowsy driving and automobile crashes," The National Highway Traffic Safety Administration (NHTSA) , 2013

[2] Qiang Ji, Zhiwei Zhu, and Peilin Lan, "Real-time nonintrusive monitoring and prediction of driver fatigue," *IEEE Trans. on Vehicular Technology*, vol 56, no. 4, July 2004.

[3] Jian-Da Wu and Tuo-Rung Chen. "Development of a drowsiness warning system based on the fuzzy logic images analysis," *Expert Systems with Applications*, 34.2 (2008): 1556-1561.

[4] Ellen M. Ayoob, Richard Grace, and Aaron Steinfeld, "A user-centered drowsy-driver detection and warning system," in *Proc. The 2003 conference on Designing for User Experiences*, vol. 6, no. 7, 2003.

[5] Qiang Ji and Xiaojie Yang, "Real-time eye, gaze, and face pose tracking for monitoring driver vigilance," *Real-Time Imaging*, 8.5 (2002): 357-377.

[6] H. H. So and K. L. Chan, "Development of QRS detection method for real-time ambulatory cardiac monitor," in *Proc. The 19th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Oct. 1997, pp. 289–292.

[7] Richard Kobza, et al., "Twelve-lead electrocardiography in the young: Physiologic and pathologic abnormalities," *Heart Rhythm*, 2012, 9.12: 2018-2022.

[8] Edwin Hewitt, and Robert E. Hewitt, "The Gibbs-Wilbraham phenomenon: An episode in Fourier analysis," *Archive for History of Exact Sciences*, 1979, 21 (2): 129–160

[9] R. D. Berger, S. Akeselrod, D. Gordon, and R. J. Cohen, "An efficient algorithm for spectral analysis of heart rate variability," *IEEE Trans. Biomed. Eng.*, vol. BME-33, pp. 900–904, Sept. 1986.

[10] Glenn Myers, et al., "Problems in measuring heart rate variability of patients with congestive heart failure," *Journal of Electrocardiology,* 25 (1992): 214-219.

[11] Robert E. Kleiger, et al., "Decreased heart rate variability and its association with increased mortality after acute myocardial infarction," *The American Journal of Cardiology,* 59.4 (1987): 256-262.

[12] Marek Malik, et al., "Heart rate variability in relation to prognosis after myocardial infarction: selection of optimal processing techniques," *European Heart Journal* 10.12 (1989): 1060-1074.

[13] P. Jiapu and W. J. Tompkins, "A real-time QRS detection algorithm," *IEEE Transactions on Biomedical Engineering*, vol. 32, no. 3, pp. 230-236, Mar. 1985.

[14] H. A. N. Dinh, D. K. Kumar, N.D. Pah, and P. Burton, "Wavelets for QRS detection," in *Proc. The 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Oct. 2001. vol. 2, pp. 1883-1887.

[15] Y. Li and X. Chen, "A robust R-Wave detection algorithm in ECG signal," in *Proc. International Conference on Transportation, Mechanical, and Electrical Engineering*, Dec. 2011, pp. 2433-2436.

[16] Chung-Chin Chen, *A Portable Tele-Emergent System Supporting Electrocardiogram Discrimination*, MS Thesis, Institute of Computer, Communication, and Control, Department of Electronic Engineering, NTUT, 2004.