（様式６号）「課程博士用」

学 位 論 文 の要 旨

専　攻　名	システム工学 専　攻	氏　名（ふりがな）	ZITI FARIHA BINTI MOHD APANDI（じてぃ ふぁりーは ぴんてぃ もはまど あぱんて） ㊞

学位論文題目

Development of Noise-Tolerant Method for Arrhythmia Heartbeat Detection in Ambulatory Electrocardiogram

（英訳又は和訳：携帯型心電計における不整脈心拍のノイズ耐性検出方法の開発）

Cardiovascular diseases have become one of the leading causes of mortality globally, and they are forecasted to remain so in the future. One of the common class of cardiovascular diseases is abnormal heart rhythms or arrhythmia. Some types of arrhythmias can be life-threatening, resulting in sudden cardiac death. The heartbeat classification is an approach to detect the arrhythmias in electrocardiogram (ECG) signal. One of the most important processes in heartbeat classification is the heartbeat detection or also known as QRS complex. However, detecting heartbeat is more challenging in an ambulatory ECG signal because the level of noise and artifacts produced during the daily life activities is higher compared to in a hospital setting. It is difficult to identify the QRS complex in the signal during high-intensity physical activities and low signal-to-noise-ratio, affecting the performance of heartbeat detection in the heart monitoring system. Therefore, it is necessary to develop a robust heartbeat detection method against the noise and artifact produced during daily-life activities. The aim of this study was to develop a noise-tolerant heartbeat detection method for heartbeat classification in order to detect the arrhythmias in ambulatory signals. To achieve that aim, three objectives were developed.

The first objective was to study and analyze the effects of noisy signal on the heartbeat detection performance. The relationship between the characteristics of the ECG noises produced in the ambulatory ECG signals recorded during daily life activities and the heartbeat detection performance was investigated. For this purpose, three well-known algorithms to detect the heartbeat were employed. The detection algorithms were evaluated using two types of ambulatory datasets: the ECG signal from MIT-BIH Arrhythmia database and the ECG-noise simulated signals with different intensity of baseline wander, muscle artifact and electrode

続紙　有☑　無☐

氏　名（ふりがな）	じてぃ　ふぁりーは　びんてぃ　もはまど ZITI FARIHA BINTI MOHD あぱんて APANDI　㊞

motion artifact. The findings showed that the signals contaminated with noise decreased the potential of heartbeat detection in ambulatory signal, with the poorest performance coming from the electrode motion artifact. In conclusion, none of the algorithms was able to detect all QRS complex without any false detection at the highest level of noise. The electrode motion artifact influenced the heartbeat detection performance the most compared to the muscle artifact and baseline wander, showing the highest number of misdetections and false detections.

The second objective was to propose and develop a robust and noise-tolerant heartbeat detection method. For this purpose, the threshold-based heartbeat detection was developed. To improve the performance of the detection method, the Savitzky-Golay moving average and autocorrelation technique were used to reduce false detections in this study. The proposed method consisted of processing and QRS detection stages using six techniques, including band-pass filter, derivative, squared, Savitzky-Golay moving average, autocorrelation and adaptive threshold. The Savitzky-Golay moving average was used to smoothen the signal data and autocorrelation was used to generate the period of the heartbeat and to refine the candidate QRS complex. The proposed method was evaluated using three different datasets, including the real data during walking and running on the treadmill. Based on the results, the proposed method performed well despite its use in different noisy conditions. Based on the results, it could be concluded that the proposed method had a good performance, especially in electrode motion artifact.

Finally, the arrhythmia detection system was developed by using the heartbeat classification approach to achieve the third objective. The heartbeat classification approach consisted of four stages: ECG signal processing, heartbeat segmentation, feature extraction and classification. The proposed noise-tolerant heartbeat detection method was adopted and the set of features that represented each heartbeat was extracted for the classification. Fourteen features were extracted separately to represent each heartbeat, with seven features of heartbeat interval and seven features of ECG morphology. After evaluating the classification algorithms, the k-NN algorithm was used to construct the classification model and as tests in the experiments. Based on the results, the proposed heartbeat classification performed better when classifying normal and ventricular beats, except the supraventricular beats. In the noisy ECG signal, the classification method also performed better than using pan Tompkins algorithm as the heartbeat detection.