CAN WE DETECT HEART ATTACK FROM PAIN INDUCED SKIN SYMPATHETIC NERVE ACTIVITY SIGNALS?

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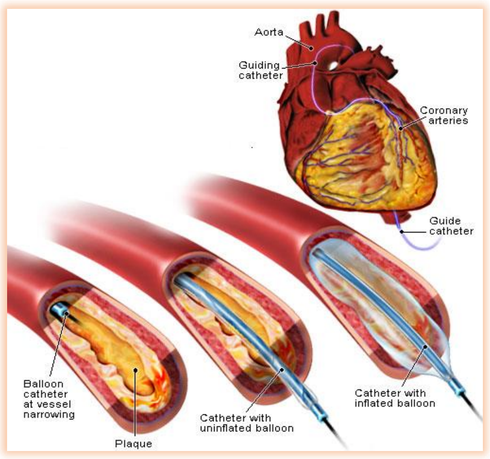
MOTIVATION

- ECG has been an important part of clinical practice for diagnosis of various cardiovascular diseases by detecting electrical signals from heart.
- Diagnostic information in ECG is contained below 150 Hz, therefore American Heart Association recommends bandwidth of 0.5 Hz to 150 Hz for monitoring of ECG signals.
- In conventional ECG devices, higher frequency signals that contain activities of skeletal muscle (EMG) and nervous system are eliminated by this filtering.
- Recent studies showed that it is possible to non-invasively record higher frequency signals in humans, called skin sympathetic nerve activity (SKNA), by using equipment which has wide frequency bandwidth and high sampling rate [1].

DATASET CONSTRUCTION

- GU-ECG database is a clinical research study performed to determine transient ECG changes during coronary artery occlusion caused by PTCA.
- Coronary artery occlusion during PTCA induces AMI and produces ST segment and T wave changes in ECG [2].
- GU-ECG simulates heart attack, hence it serves as excellent testbed for development of various AMI detection techniques.
- It is largest database documenting high frequency ECG changes during AMI.



- It is constructed by acquiring wideband recordings from AMI patients diagnosed by cardiologists at Gazi University, Faculty of Medicine.
- It includes ECG recordings of 108 patients acquired before and during PTCA by using equipment with wide frequency bandwidth and high sampling rate.
- Before PTCA, pre-inflation recordings were acquired at rest prior to catheter insertion to coronary arteries.
- During PTCA, inflation recordings during balloon inflation in major coronary artery were acquired.

PROBLEM DEFINITION

- Electrical signals obtained from skin surface y_i contains sympathetic nerve activity (SKNA), motor and sensory nerve activities, skeletal muscle activity (EMG) and myocardial activity (ECG).

$$y_i(t) = c_i(t) + q_i(t) + m_i(t) + n_i(t), \quad i = 1,..,N$$

- SKNA will be delayed and will decrease in amplitude as it moves away from its source, which can be modeled by using amplitude and delay parameters.

$$q_i(t) = \alpha_i\, q(t - \tau_i), \quad 0 < \alpha_i < 1$$

Assumption: SKNA is uncorrelated with sensory and motor nerve activities and EMG.

- Robust estimation of SKNA for known amplitude and delay parameters:

$$\hat{q}(t) = \frac{\sum_{i=1}^{N} \alpha_i\, y_i(t + \tau_i)}{\sum_{i=1}^{N} \alpha_i^2}$$

CONCLUSION

- By using state-of-the-art signal processing and machine learning methods, developed technique detects anomalies in SKNA and ECG, hence it provides additional diagnostic information to ECG for reliable diagnosis of AMI.
- Proposed technique simultaneously detects anomalies in SKNA and ECG, which considerably increases detection performance of AMI.
- Thus, it can provide significant decrease in mortality rates of ischemic heart diseases.
- It can expand application of ECG to simultaneously detect SKNA anomalies to perform robust detection of various cardiovascular diseases.

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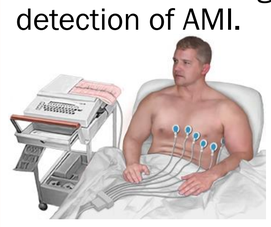
METHODOLOGY

PROPOSED AMI DETECTION TECHNIQUE

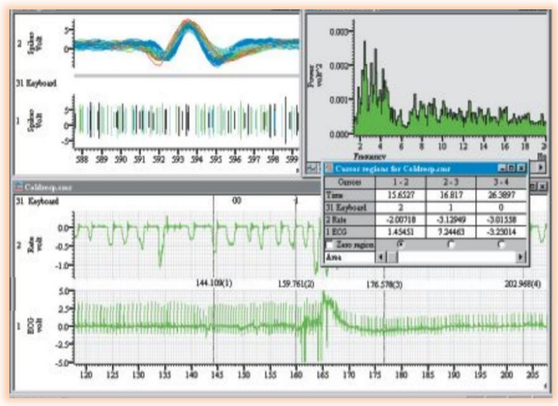
This study proposes a new technique which detects anomalies in SKNA and ECG by using state-of-the-art signal processing and machine learning methods to perform robust detection of AMI.



Raw Data → Preprocessing → SKNA → Feature Extraction → SKNA Features → Classification

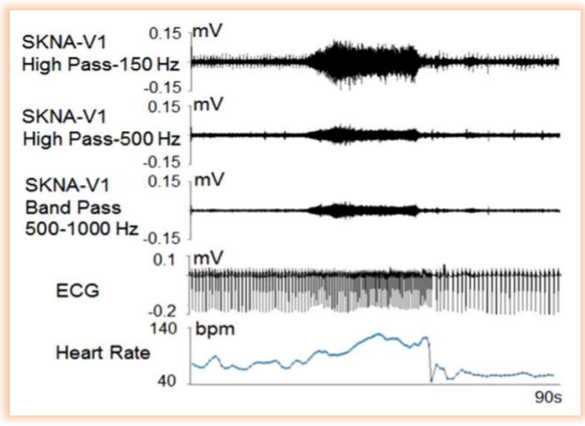
SIGNAL CONDITIONING TECHNIQUE

- SKNA and ECG are obtained by implementation of signal conditioning technique to wideband recordings on GU-ECG database which are acquired before and during AMI.



For increasing cut-off frequencies of filter:

- EMG signals are eliminated, which increased specificity of SKNA recording.
- However, majority of SKNA is filtered out, which reduced sensitivity of SKNA recording.



- *There is an increase in SKNA during AMI.*
- *Increase in SKNA is associated with ST/T anomalies in ECG during AMI.*

➡ SKNA of a patient during cardiac arrythmia [3].

FEATURE EXTRACTION TECHNIQUE

- Novel feature extraction technique which obtains discriminative SKNA and ECG features that are critical for robust detection of AMI is developed.

Absolute SKNA

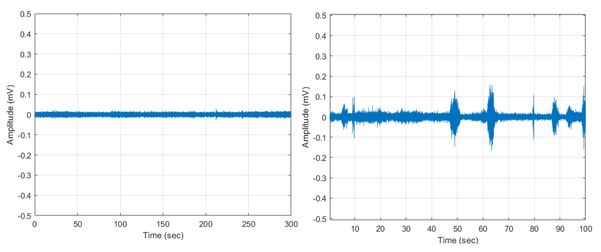
$$abs[n] = \sum_{m=0}^{N-1} |s[n+m]|$$

Average SKNA

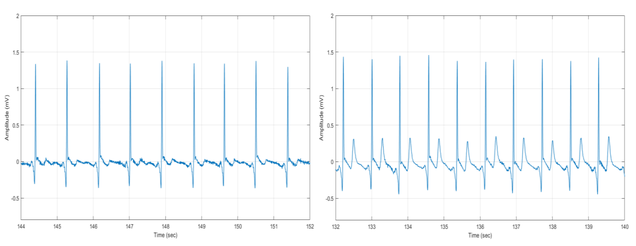
$$ave[n] = \frac{1}{N} \sum_{m=0}^{N-1} |s[n+m]|$$

Maximum SKNA

$$max[n] = \max_{0<m<N} (s[n+m])$$



SKNA of a patient before and during AMI obtained by implemention of proposed technique to GU-ECG database.

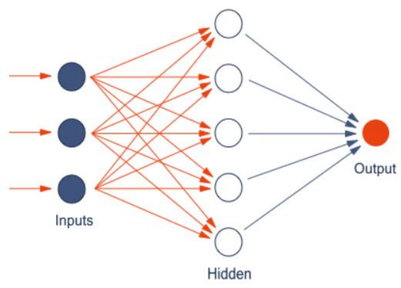


ECG of a patient before and during AMI obtained by implemention of proposed technique to GU-ECG database.

CLASSIFICATION TECHNIQUE

- Supervised learning technique based on artificial neural networks (ANN) which uses discriminative SKNA and ECG features to perform robust detection of AMI is developed.
- Feed-forward ANN consists of input layer with six input units, hidden layer and output layer with one output unit.

PERFORMANCE MEASURES	PERFORMANCE RESULTS (%)
Accuracy	86.5
Detection Rate	89.1
False Alarm Probability	18
Positive Predictive Value	90.2
Negative Predictive Value	76.8
Specificity	82



- Performance results of proposed technique with optimum ANN, discriminative SKNA and ECG features over GU-ECG database indicate that technique provides highly reliable detection of AMI.

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