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Emotion Recognition using Wireless Signals

The main objective of this paper lies in **inferring a person's emotions from RF signals reflected off his body**. EQ-Radio transmits an RF signal and analyzes its reflections off a person's body to recognize his emotional state (happy, sad, etc.). There are existing approaches such as on-body ECG monitors that can detect heartbeats. The key enabler underlying EQ-Radio is a new algorithm for extracting the individual heartbeats from the wireless signal at an accuracy comparable to on-body ECG monitors. The resulting beats are then used to compute emotion-dependent features which is then classified.

The key challenge in this work is to identify the inter-beat interval (IBI) - The EQ-Radio Emotion recognition needs accurate measurements of the length of every single heartbeat. Only when IBI has a high accuracy of 99%+ will the method work.

The authors claim the following :

1. EQ-Radio is the first system in the world that can recognize emotion using just wireless signals.
2. The IBI extraction algorithm works with an accuracy of 99.6% - which is needed.
3. The user study and empirical results show that EQ-Radio is as accurate as ECG-based emotion recognition.

In order to extract IBI, the authors do the following :

1. **Remove the breathing signal** : Breathing masks the heartbeats. It is observed that Breathing is slow and steady while heartbeat involves rapid contraction of muscles. Thus, to separate out the two signals, the authors propose using acceleration filter.
2. **Heartbeat segmentation** : Although heartbeat repeats with certain shape (template), it can be longer or shorter and may not be the same size. In order to identify each heartbeat cycle, the idea is to find a segmentation with segments most similar to each other – i.e., to minimize the variation across segments. The goal of the algorithm is to find the optimal segmentation $\mathbf{S^*}$ that minimizes the variance of segments, which can be formally stated as follows: $\mathbf{S^* = \arg\min_S Var\ (S)}$.

Along with S, the authors look at **μ** which is the morphology.

Thus, their algorithm recovers both segmentation **S** and template **μ**.

- Joint optimization: $\underset{\mathcal{S},\boldsymbol{\mu}}{\text{minimize}} \sum_{s_i \in \mathcal{S}} \|s_i - \omega(\boldsymbol{\mu}, |s_i|)\|^2$

segmentation template warping

Since both segmentation and template have linear complexity, we are guaranteed to obtain optimum values.

For the experiments, the authors considered 37 Features which are similar to ECG-based methods

They looked at the variability of IBI and the irregularity of breathing to classify among the four emotions.

For emotion classification, the authors tried to recognize emotion using physiological features. They used L1-SVM classifier, selected the features and trained the classifier at the same time.

They used a standard 2D emotion model with Joy, Anger, Sadness and Pleasure in the four quadrants of a 2D plane.

For evaluation, the authors used ECG values of 30 subjects with over 130,000 heartbeats. They found that the median IBI estimation error rate is 0.4% and the 90th percentile error is 0.8%.

For the implementation, the authors used a FMCW radio of 5.5 GHz to 7.2 GHz and it had sub-mW power.

To test how well their system works, the authors conducted an experiment: 12 subjects (6 female and 6 male)

The subjects were asked to prepare personal memories for each emotion which would elicit certain emotion with prepared memories. The system would then classify the expressions every 2 minutes to an emotional state. The Ground truth would be self-reported for each 2-min period.

The accuracies of EQ-Radio were almost on par with on-body ECG monitors.

However, there were a few points that needed more clarity :

Questions :

1. The authors have not mentioned the variation in accuracies between the two genders. Only then will we know whether the system is robust to change in genders.

2. The subjects recruited were actors who can show good facial expressions. How would the accuracies change for a normal person when the expressions may not be so visible?

More details about the paper

Zhao, M., Adib, F., & Katabi, D. (2016, October). Emotion recognition using wireless signals. In Proceedings of the 22nd Annual International Conference on Mobile Computing and Networking (pp. 95-108).