Emotion Recognition using Wireless Signals

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The Problem Definition:

The paper is an application and extension of the papers (by the same authors) namely: "Smart Homes that Monitor Breathing and Heart Rate" and "3D Tracking via Body Radio Reflections". With advancements in technology, the research and development in the field of wireless have become quite vast. Many software applications have been popularized over years, which aim to track the user activities like analysis of body parts, gesture tracking (for smart homes, etc.), breathing and heart rate, emotions, etc. Most of these solutions depend on the smart device on the user or in their vicinity (for indoors) or imaging, etc. Not only this, but most of these solutions require a lot of calibrations and empirical data to be stored or rely on image processing, and audiovisual techniques, that go to an extent where the user might feel his/her privacy being invaded (like using the microphone on the user's phone to detect the signatures around him). This paper presents the idea of EQ-radio that can conclude human emotions such as anger, sadness, joy, and pleasure from the RF signals reflected off the user's body without any device on the user's body. Moreover, it doesn't even require the user to be in close vicinity of the setup device.

Key Idea:

The solution EQ-Radio works on the idea of using antennas (as used in the paper 3D Tracking via Body Radio Reflections) to analyze the RF signals reflected off from the user's body to detect the user's heartbeat. Then compute the pattern between two heartbeats (the minute variations of each individual beat length) to determine the user's emotions. Although this sounds simple there are certain challenges involved in the detection of the heartbeat of the user from the reflected RF signals considering the impact of breathing is usually orders of magnitude higher than that of the heartbeat. Also, the RF signals lack sharp beats which makes it difficult to detect the difference between the signal reflected due to breathing or quasi-static movement and heart rate. Moreover, the individual beats need to be segmented within a few milliseconds because the difference in inter-beat intervals (IBI) is only a few tens of milliseconds. All these challenges are handled using the Beat Extraction algorithm, which is the heart of this solution. Further, an SVM classifier is used to differentiate between different stages. The paper claims to achieve an accuracy of 87% (when the system is trained on each subject separately) and 72.3% otherwise.

Important Details:

1. There are three main components namely: FMCW radio, beat extraction algorithm, and emotion classification sub-system.
2. The beat extraction algorithm mitigates the impact of breathing with an intuition that the chest displacement due to breathing is orders of magnitude larger than minute vibrations due to heartbeats, and the acceleration of breathing is smaller than that of heartbeats.
3. The morphology of the heartbeat signal is unknown and varies as an individual, therefore the beat shape needs to be learned as the segmentation (RF reflection to individual heartbeat) is performed.

4. The joint optimization technique is used for the segmentation of the heartbeat. Where the problem is divided into two sub-problems: the first one learns a template of the heartbeat given a particular segmentation, while the second finds the segmentation that maximizes resemblance to the learned template.
5. EQ-Radio uses FMCW, a radar technique to capture the reflections of the RF signal from the user and separated the RF reflections from different objects/bodies into buckets based on their reflection time. Further, eliminates the reflections from the static objects in the environment which do not change with time.

My Thoughts and Criticism:

The paper presents a great application for detecting heartbeat using RF signals and then determining the mood of the user with relevant observations and proofs. It can be observed that the author has tried to be open about the ideas and challenges faced while implementing this solution. Also, the paper well explains what are the factors that make EQ-Radio different from already existing solutions.

However, a few of the assumptions and scenarios that led me to further questions and thinking are:

1. Will the solution work when there are multiple users in the same bucket?
2. The assumption made to the Beat extraction algorithm is that breathing is usually slower and more stable than the heartbeat. What if the user is working out or running or performing high-breathing intensive activities?
3. The Experiment/analysis are performed on 30 subjects by showing them the pictures or asking them to remember old memory. Which is a great approach, but this experiment should also be beta tested on multiple real scenarios like large gatherings for parties or funerals, or movie theaters to avoid any bias in the test results.
4. The idea that the subject can be a kid, an animal, a young healthy adult, or an elderly sick/healthy person is not considered while testing.
5. EQ-Radio relies on the fact that the user is static or Quasi-static but in real-time, the user can be in motion.
6. To better rule-out multipath, the EQ-Radio relies on the assumption that with time there needs to be a training data set that can determine the static distance from the reflectors, but reflectors can also be non-static over time (for example moving an office chair).
7. The medium of the environment (where these RF signals will be reflected) is not considered for observation. As there can be a lot of interference as the medium of transmission varies leading to deteriorated signals.
8. Intensive testing needs to be done if the system needs to be used for commercial purposes as many people can till day bluff polygraphy. In the same way, many people can also control their heart rate and challenge the accuracy of the EQ-Radio.
9. There can be multiple emotions than just anger, sadness, joy, and pleasure.