Title: Emotion Recognition using Wireless Signals

Abstract

* Demonstrates a new technology called EQ-Radio that can infer a person's emotions from RF signals reflected off their body
* Transmits an RF signal, analyzes reflections off the body to recognize emotional state (happy, sad, etc.)
* Key enabler is a new algorithm to extract individual heartbeats from the wireless signal with accuracy comparable to ECG monitors
* Uses heartbeats to compute emotion-dependent features that feed into a machine learning emotion classifier
* Shows emotion recognition accuracy on par with state-of-the-art systems requiring ECG monitors

1. Introduction

* Motivates emotion recognition and its applications in areas like smart homes, advertising, mental health monitoring
* Discusses limitations of existing emotion recognition approaches based on audiovisual cues (miss inner feelings) or physiological sensors like ECG (requires contact with body)
* Proposes using RF signals that reflect off the body to sense emotions in a contactless manner

1. Background & Related Work

* Surveys prior work on emotion recognition using audiovisual techniques and physiological measurements
* Discusses RF-based sensing techniques for tracking motion, gestures, activities and vital signs

1. EQ-Radio Overview

* Three main components: FMCW radio to capture RF reflections, beat extraction algorithm, emotion classification subsystem
* Uses RF reflections to extract breathing pattern and heartbeats, which are mapped to emotional states

1. Capturing the RF Signal

* Uses Frequency Modulated Carrier Waves (FMCW) radar to transmit RF signal and measure reflections
* Separates human reflections from static objects, focuses on quasi-static periods

1. Beat Extraction Algorithm

* Key challenge is extracting individual heartbeats from noisy RF reflections without known morphology
* Mitigates breathing interference by operating on signal acceleration
* Formulates joint optimization to recover beat morphology and segmentation
* Iterates between updating segmentation given morphology template and updating template given segmentation

1. Emotion Classification

* Adopts 2D emotion model with valence and arousal axes (joy, pleasure, sadness, anger)
* Extracts 27 features from inter-beat intervals based on literature
* Extracts respiration features from breathing signal
* Handles person-dependence by computing feature deltas from neutral state
* Uses l1-regularized SVM for feature selection and classification

1. Evaluation

* Implementation details of FMCW device and signal processing
* Evaluates beat extraction accuracy against commercial ECG (3.2ms mean error)
* Evaluates emotion recognition accuracy - 87% person-dependent, 72.3% person-independent
* Compares to ECG-based (88.2%/73.2%) and image-based (39.5%) emotion recognition
* Analyzes impact of beat estimation errors on emotion recognition accuracy

Title: Battery-free wireless imaging of underwater environments

Introduction

* Underwater imaging is important for understanding marine environments, climate change, sustainability, defense, robotics, geology, space exploration, and food security.
* Most of the ocean and marine life remains unobserved and undiscovered due to limitations of existing underwater imaging methods that require tethering for power and communication.

Wireless Imaging Method Design and Architecture

* Describes a battery-free wireless imaging method using acoustic energy harvesting and acoustic backscatter communication.
* A remote acoustic projector transmits sound which is harvested by a piezoelectric transducer to power up the sensor.
* An ultra-low-power CMOS camera captures images using active RGB illumination LEDs.
* Images are communicated wirelessly via piezo-acoustic backscatter to a hydrophone receiver.

Communication through Backscatter

* Uses piezo-acoustic backscatter to communicate by modulating reflections of incident sound waves, requiring very low power.
* Switches impedance between open and matched load to modulate the radar cross-section.

Uplink Decoding

* Explains the robust demodulation and decoding pipeline at the receiver to recover transmitted packets.

Energy Harvesting and Power Management

* Harvests acoustic energy and stores it in a supercapacitor before powering other components to ensure sufficient charge.
* Utilizes a DC-DC converter as a power gating mechanism to buffer energy before operation.

FPGA Control and Logic

* Uses an FPGA to control imaging and communication in two phases to deal with bandwidth limitations.
* Imaging phase: Captures image segments and stores in FPGA memory.
* Communication phase: Transmits stored segments via low-power backscatter.

Power Analysis

* Overall power consumption of 276 μW for active color imaging and 112 μW for passive monochrome imaging.
* Leverages ultra-low-power components like backscatter, FPGA, and dual oscillator clocks.

Experimental Demonstrations

* Demonstrated wireless battery-free imaging of animals, plants, pollutants, and localization tags.
* Evaluated harvesting capabilities, communication range, SNR, and BER.

Conclusion

* Enables scalable, continuous, long-term in-situ underwater imaging using fully self-sustaining wireless cameras.
* Potential applications in marine discovery, aquaculture monitoring, climate change studies, defense, and more.

"Vital-Radio: Monitoring Breathing and Heart Rate with Commodity WiFi" with key points and side headings:

**Introduction**

* Evolution of ubiquitous sensing technologies has led to smart environments that can monitor daily activities
* Proposes Vital-Radio, a wireless sensing technology to monitor breathing and heart rate without body contact
* Exploits that wireless signals are affected by motion like chest movements from breathing and skin vibrations from heartbeats
* Envisions Vital-Radio enabling smart homes to monitor vital signs without instrumentation for enhanced health awareness

**Related Work**

* Previous work focused on either vision-based techniques requiring user to face camera, or wireless systems with constraints like one user staying still in close proximity

**Theory of Operation**

**Isolate Reflections from Different Users**

* Uses FMCW radar technique to separate reflections from different distances into buckets
* Eliminates reflections from static objects by subtracting consecutive measurements

**Identify Reflections with Breathing and Heartbeats**

* Analyzes phase variations in isolated reflections to detect breathing and heartbeat motions
* Breathing causes periodic expansions/contractions of chest, varying distance to device
* Heartbeats cause minute body movements (ballistocardiography) modulating signal

**Extract Breathing and Heart Rates**

* Performs FFT on time-series of phase variations
* Detects peak at breathing rate frequency
* Detects second peak at heart rate after removing breathing component

**Implementation**

* Transmits WiFi OFDM signals in 5 GHz band
* Can monitor up to 8m away, through walls
* Doesn't require line-of-sight or user facing device

**Evaluation**

* Validated with 14 subjects, compared to FDA-approved breathing and heart rate monitors
* 99%+ accuracy for breathing rate up to 8m away
* 98%+ accuracy for heart rate up to 8m away
* Can monitor up to 3 people simultaneously
* Works during computer use, exercise, etc.

**Conclusion**

* Vital-Radio enables smart home monitoring of breathing/heart rate without contact
* Potential for improved health awareness and healthcare impact

Here is a more detailed and elaborated summary of the key points from the "Augmenting Augmented Reality with Non-Line-of-Sight Perception" paper:

Introduction

- Augmented reality (AR) headsets today are limited to line-of-sight perception using cameras/vision sensors. This prevents them from operating effectively in cluttered industrial environments where many objects are occluded.

- The paper proposes using radio frequency (RF) signals that can traverse occlusions to provide AR headsets with non-line-of-sight (NLOS) perception capabilities.

- Specifically, it leverages UHF RFID tags which are widely adopted in supply chains to enable object localization and tracking even when fully occluded.

System Overview

- X-AR is designed to guide a user wearing the AR headset to locate and verify pickup of specific RFID-tagged target items in the environment.

- It introduces three key innovations: 1) AR-conformal wideband antenna, 2) RF-visual synthetic aperture radar localization, 3) RF-visual verification

AR-Conformal Antenna Design

- A novel lightweight (<1g), conformal antenna was designed to integrate with the AR headset visor without obstructing view.

- Antenna uses tapered shape with slots to achieve 200 MHz wideband operation around 900 MHz required for RFID localization.

- Rigorous simulations and measurements validated the antenna's radiation pattern, bandwidth and gain specifications while mounted on the headset.

RF-Visual Synthetic Aperture Radar Localization

- Leverages synthetic aperture radar (SAR) principle using the single conformal antenna measurements collected across multiple locations as the user moves.

- Fuses these RF measurements with visual data from the headset cameras to self-localize and create a non-uniform synthetic aperture.

- Introduces techniques to handle localization artifacts from natural human motion like head tilts and RFID backscatter radiation properties.

- Guides user by displaying the 3D localized position of the RFID tag on the AR headset visuals.

RF-Visual Verification

- Performs "reverse SAR" by leveraging mobility of the RFID tag itself after the user picks it up.

- Fuses this with the headset's hand-tracking ability to accurately verify if the user picked up the specific target RFID item.

- Shows over 95% verification accuracy even when item is occluded inside a box.

Evaluation

- End-to-end prototype implemented by integrating hardware and algorithms with Microsoft HoloLens 2.

- Evaluated over 230 trials, demonstrating:

- 9.8 cm median localization accuracy for RFID tags, even when non-line-of-sight

- Over 95% F-score accuracy in verifying correct item pickups

- Conformal antenna achieved all specified radiation and bandwidth requirements

In summary, X-AR introduces novel RF sensing hardware and algorithms tightly integrated with an AR headset to provide unprecedented non-line-of-sight perception capabilities. This enables intuitive visualization, localization and verification of occluded objects for applications like warehousing and manufacturing.