Multi-Person Localization and Non-Contact Vital Signs Monitoring Via FMCW Radar
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Motivation and Contributions
- The increase in cardiopulmonary morbidity, disease transmission and burden on medical staff has led to extensive investigation of non-contact monitoring approaches
- Remote technology such as radar does not require users to wear, carry, or interact with any additional electronic device
- We present a hardware phantom and method for multi-person non-contact vital signs monitoring (MP-NCVSM) in a noisy environment, via single-channel FMCW radar
- Our algorithmic approach is based on joint-sparse recovery (JSR) which accurately localizes humans in a cluttered scenario involving equidistant targets, where known techniques struggle
- Vital Signs-based Dictionary Recovery (VSDR) method is then used to estimate their vitals (Respiration Rate (RR) and Heart Rate (HR)) yielding superior results compared to current NCVSM approaches.

Extended SIMO FMCW Model
- We suggest the following signal model based on SIMO FMCW radar:
  \[
  y[n, k] = \sum_{m = 1}^{M} \sum_{l = 1}^{L} \sum_{v = 1}^{V} \sum_{q = 1}^{Q} \sum_{p = 1}^{P} \frac{2S}{\pi} \sum_{\lambda = 1}^{L} d_{\lambda,m,v,l} \sin(2\pi f_{\lambda,m,v,l} n) + \sum_{w = 1}^{W} w[n, k] 
  \]
- \( d_{\lambda,m,v,l} \) models the possible vibration of each object.
- The set \( \{\lambda, m, v, l\} \) includes the RR and HR of each human, denoted by \( \{\lambda, m, v, l\} \) for \( Z \leq MP \) humans in the FOV.
- Reshaping each L frames \( \Rightarrow \sqrt{Y - C\bar{X} + W} \)

Graphical User Interface
- The operator can choose between a trial of sinusoids or human thoracic vibrations as well as determining the frame rate and duration of trial
- Example of localization and NCVSM of 3 people simultaneously:
  - Two equidistant targets located approximately at 1 [m] from the radar and +10 [deg]
  - Third target located approximately at 1.1 [m] from the radar and +25 [deg]

Hardware
- Multi-person localization by the proposed JSR
- Multi-person NCVSM by VSDR and other techniques

Localization and NCVSM Results
- VSDR* method for estimating HR and RR given \( v = \{v_{1}, \ldots, v_{L}\} \):
  - Assuming that
    \[ v_{\lambda} = D_{v}v_{\lambda} + D_{v}v_{\lambda} + b_{\lambda} \]
    with known \( D_{v} \) and \( D_{v} \):
    \[ v_{\lambda} = D_{v}v_{\lambda} + D_{v}v_{\lambda} + b_{\lambda} \]

Sparsity-Based Multi-Person Localization and NCVSM
- Joint-sparse recovery for multi-person localization
  Ideal window corresponding to normal breathing frequencies
  L-axle DFT matrix
  \[ Y = D^{T}C^{T}Y \]
  \( \Rightarrow \) S
- Doppler rows recovery
  \[ X_{s} = \{C/C\}D^{T}C^{T}Y \]
- Phase extraction
  \[ v[l,f] = \text{unwrap} \{\{X_{s}[l,f]\}\} \rightarrow Z_{1}, \ldots, Z_{L} \]

Graphical User Interface
- GUI: Parameter setting, multi-person localization and NCVSM
- Display: Graphical User Interface
- Hardware: Radar, Multi-person localization and NCVSM
- Plate #1: Human 1
- Plate #2: Human 2
- Plate #3: Human 3