Non-contact Physiological Sensing w/ Radar and Camera

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Research Overview

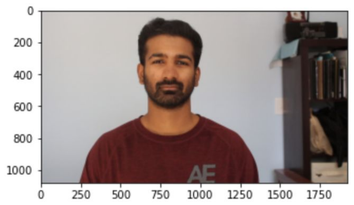
Prior work has shown the ability to measure heart and respiration rate signals from facial-video [1] and from mmWave radar [2]. However, both modalities underperform under different environmental conditions. Video based rPPG performance suffers in low-light environments and on individuals with darker complexions, while mmWave based solutions struggle with signal integrity at distance. This work seeks to balance these tradeoffs and build a more robust solution to non-contact physiological sensing by fusing inputs from both camera and radar sensing modalities.

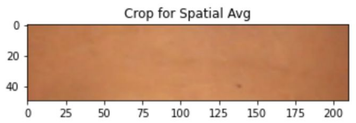
Camera Based Sensing

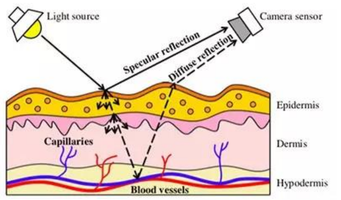
Remote Photoplethysmography (rPPG)
- Capillary dilation causes 'micro-blush"
- Signal appears in RGB channel of camera video
- Used to derive heart signal

Balisto - Respiration Signal
- Lung function causes body-motion
- Used to derive respiration signal

Camera Trade-offs
- Robust at distance
- Suffers in low-light and on darker skin tones







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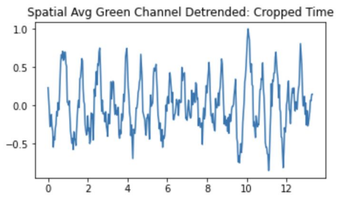
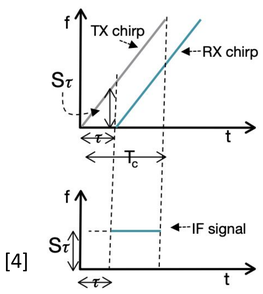


Radar Based Sensing

Frequency Modulated Continuous Wave mmWave Radar
- FMCW radar outputs chirps sweeping from 60 - 64 GHz
- Intermediate frequency proportional to distance
- Phase correlated to small changed in distance

Use of Phase Signal
- Phase signal used for heart and respiration signal derivation
- Heart signal masked by larger respiration signal and body movements

Radar Trade-offs
- Can produce extremely high-fidelity signals
- Robust in low/no light conditions, and skin-tone agnostic
- SNR degrades quickly at distance (> 1 meter)



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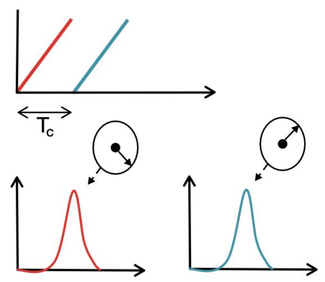
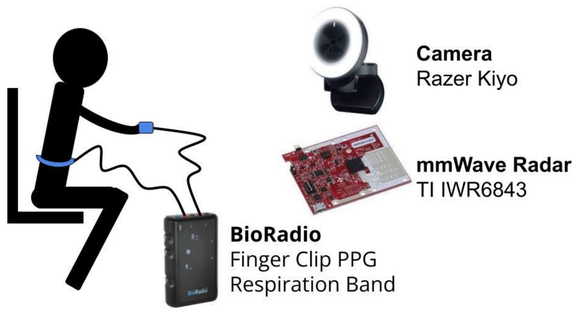


Hardware Setup

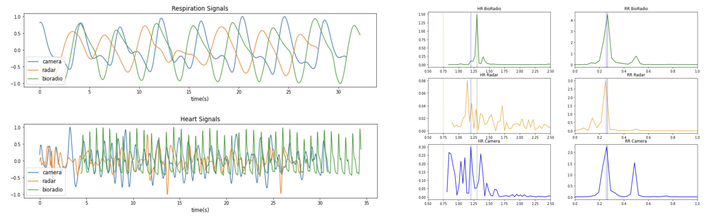


Camera
Razer Kiyo

mmWave Radar
TI IWR6843

BioRadio
Finger Clip PPG
Respiration Band

Initial Analysis



- Traditional signal processing robustly derives average heart and respiration rate, but fails to properly reproduce high-fidelity heart and respiration signals
- Respiration causes significant motion and thus is a much stronger signal than heart activity
- Deep-learning methods are required to better derive physiological signals

Future Work

Data Collection
- Gather student data
- Gather in-clinic data
- Multiple distances / lighting conditions / racial-demographics / etc.

Deep Learning
- Sensor fusion network
- Multi-task attention network

Impact
- Distance / lighting / skin color robust physiological sensing network

References

[1] Liu, X., Fromm, J., Patel, S. and McDuff, D., 2020. Multi-task temporal shift attention networks for on-device contactless vitals measurement. Advances in Neural Information Processing Systems, 33, pp.19400-19411.

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