ECE 239AS Fall 2020

Towards an Optimal Remote Photo-Plethysmographic Framework using Weighted Ensemble Models

Swapnil Sayan Saha, Suparno Pal, Rishav Guha and Paawan Garg
University of California – Los Angeles
{swapnilsayan, suparnopal, rishavgh97, pwngarg27}g@g.ucla.edu

UCLA Samueli School of Engineering

Objective

- Achieve **near-optimal fusion** of existing state-of-the-art rPPG frameworks for **stable and accurate** remote photo-plethysmography.

- **Benchmark** performance of rPPG techniques with varying hyperparameters on standard rPPG video datasets.

- **Explore computational imaging** techniques to improve BVP estimation.

Fusion Intuition

$$\min_{w} \frac{1}{N} \sum_{j=1}^{N} |(H_j - \sum_{i=1}^{n} w_i S_{i,j})| + \sum_{j=1}^{N} \sqrt{\frac{(H_j - \sum_{i=1}^{n} w_i S_{i,j})^2}{N}}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} w_i = 1, \quad 0 \leq w_i \leq 1$$

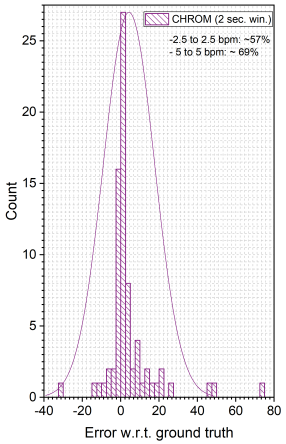
- Linear optimization of multiple rPPG models on the sum of the residuals and absolute deviation

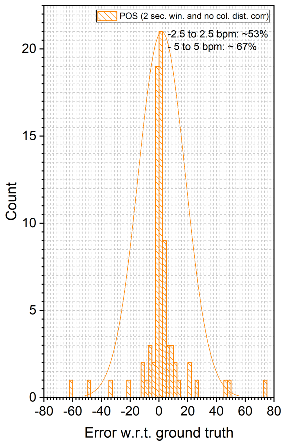
- Output: Near-optimal weights for the ensemble model.

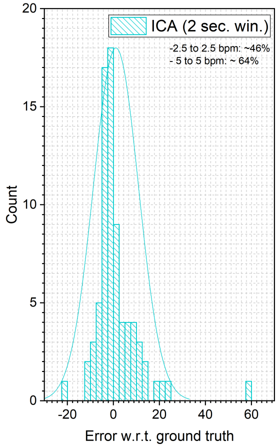
Approach/Algorithms

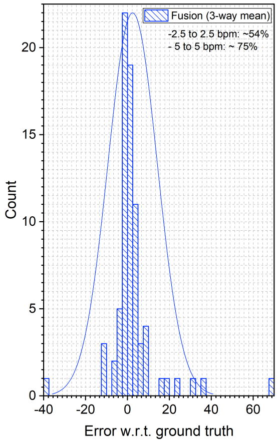
- Face detection and tracking: Viola-Jones Cascade with KLT tracking
- Skin Segmentation: Threshold-based RGB and YbCbCr
- 5 analytical algorithms from iPhys toolbox:
  - GREEN: Fourier analysis of spatially averaged pixels in HR periodicity
  - ICA: Use BSS to remove motion and noise artifacts via JADE
  - CHROM: Project normalized pixel values in the chrominance plane
  - POS: Project normalized pixel values in the “orthogonal-to-skin” plane
  - BCG: Use BSS to extract head movement caused by cyclical blood flow
- 2 benchmark datasets (60 mins, 105k frames):
  - UBFC-RPPG
  - Ostankovich-Prathap-Afanasyev (OPA)
- Hyperparameters: Window size, skin segmentation and color distortion filtering

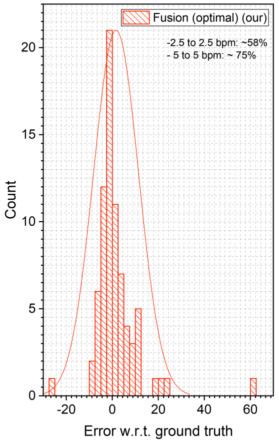
Results (overall)

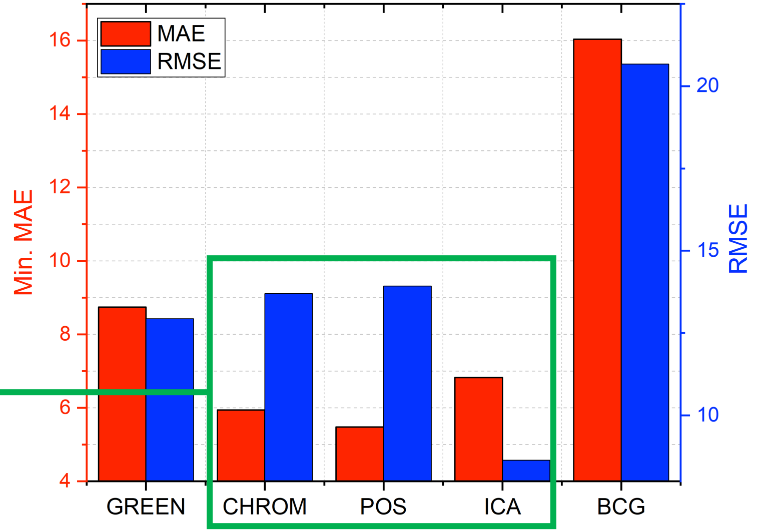


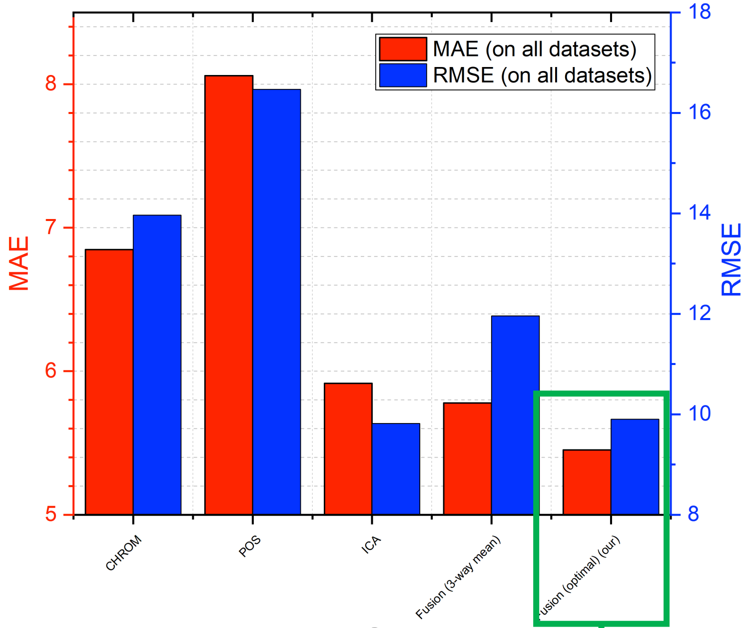






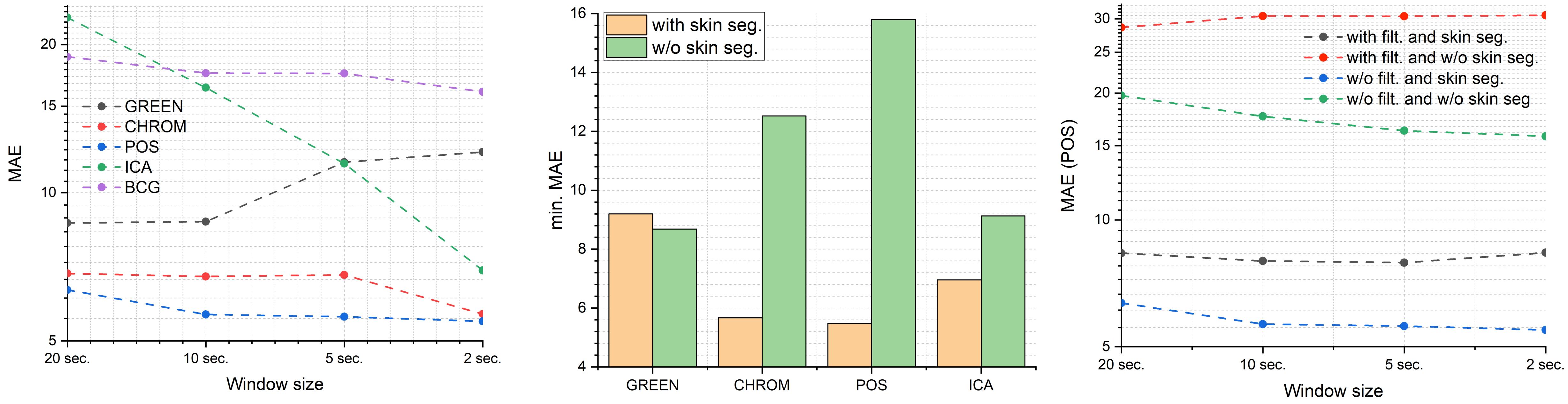






- **CHROM, POS and ICA** have lowest RMSE and MAE.
- Proposed fusion framework with weighted CHROM, POS and ICA **reduces average RMSE and MAE by 24% and 18%** respectively over solo and naïve fusion techniques.
- **75%** estimates of fusion framework lie within **± 5 bpm**, 58% lie within ± 2.5 bpm.

Results (hyperparameters)



- Smaller time windows are better.
- Skin segmentation improves HR estimate.
- Color distortion filtering (for POS) degrades HR estimate.

Computational Imaging

- Camera Position: Front position offers more usable ROI

- Shutter Speed: High exposure time appears as soft-clipping distortion in rPPG signal
- ISO: Increases gain, which increases SQNR but amplifies random noise in rPPG signal
- Aperture:
  - Small: Random noise
  - Large: Pixel saturation and Bokeh effect (useful for defocusing unwanted ROI artifacts in HR periodicity)

- Color filter: Light green improves SNR of green channel by 2x.
- Polarization filter: Blocks specular reflection

- HDR imaging: Improves BVP temporal resolution

THANK YOU

For more information, check out the technical report and code at:
https://git.io/JItjr