Camera Viewpoint Effects on Remote Photoplethysmography

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Aims: Remote photoplethysmography (rPPG) enables unobtrusive cardiovascular monitoring, yet in clinical settings cameras rarely achieve optimal frontal alignment. Since rPPG signal quality depends on the geometric relationship between facial surface orientation, illumination, and camera position, lateral viewpoints may degrade heart rate (HR) estimation accuracy. We systematically evaluated how static camera perspective, independent of head motion, affects HR estimation in recent deep learning rPPG models.

Methods: Forty-nine healthy adults (27 male, 22 female, age 32.4$\pm$12.0 years) were recorded using six synchronized industrial RGB-cameras spanning frontal to lateral perspectives (azimuth 0°-81°) under controlled diffuse illumination. Synchronized finger-clip photoplethysmography provided ground-truth HR and non-overlapping 30-second segments were retained only when PPG-derived and ECG-derived HR agreed. Eight deep learning rPPG models (TS-CAN, PhysNet, DeepPhys, PhysFormer, EfficientPhys, RhythmFormer, PhysMamba, iBVPNet) were evaluated zero-shot using weights pretrained separately on four public datasets (PURE, SCAMPS, UBFC-rPPG, BP4D). Performance was stratified by residual facial motion using Mean Landmark Displacement (MLD) tertiles to isolate viewpoint as an independent factor.

Results: Frontal views consistently outperformed lateral perspectives across all model-dataset combinations. iBVPNet pretrained on PURE achieved the lowest error with 1.81 bpm Mean Absolute Error (MAE) frontally, increasing to 2.69 bpm MAE laterally. EfficientPhys pretrained on UBFC-rPPG showed the lowest frontal-to-lateral MAE ratio (1.37$\times$), while DeepPhys reached up to 3.15$\times$. Pairwise comparison of frontal versus lateral camera groups confirmed significantly higher MAE for lateral views at all motion levels (low MLD: median MAE 5.84 vs. 7.40 bpm, Δ=1.56, p=0.0014, mid: 5.87 vs. 7.37, Δ=1.49, p=0.0008, high: 7.24 vs. 8.63, Δ=1.39, p=0.0014, Wilcoxon, Benjamini-Hochberg corr.), confirming that static camera angle alone degrades accuracy by approximately 20-27% independently of subject movement.

Conclusion: Camera placement critically affects rPPG reliability for clinical cardiovascular monitoring. These findings underscore the need for viewpoint-aware training strategies and diverse angular coverage in training data to enable robust deployment in real-world healthcare environments.