Non-Contact Sensing of Vital Signs, Physiological Perspective on Current Research and Future Research Directions

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Introduction

Wearables and Apps are putting “health on the move”

Usable and clinical grade vital sign monitoring is corner stone of telemedicine.
  ◦ Too many devices
  ◦ Difficult to use
  ◦ Accuracy (medical grade)
  ◦ Expensive

If vital sign sensing can be non-intrusive as well comprehensive and integrated, this will be a great boon for telemedicine

Emergence of wearable and non-contact sensing is a good development in this step.
Non-Contact Vital Sign Monitoring

Has been tried; following are important

- Infra-red (IR) video
- Doppler radar sensor
- Ultrasound
- Laser Doppler
- Thermal imaging
- Video camera

http://cargocollective.com/guanghao_sun/Non-contact-Vital-Signs-Monitoring

http://www.ece.rice.edu/~mk28/distancePPG/


http://www.cocooncam.com/
Camera Based Vital Sign Monitoring

- Based on the principle of photoplethysmographic (PPG) imaging.
  - PPG is a non-invasive technique which detects the blood volume changes in a blood vessel, during cardiac cycle using the principle of wavelength-dependent variation in light absorption coefficient for different tissues.
  - Parameters: HR, HRV, RR, SpO2, Temperature, NIBP.

Tamura et al., Wearable photoplethysmographic sensors—past & present. Electronics, 2014
Heart Rate

Challenges and Achievements

- Movement
- Face resolution
- Region of interest (~95-99%)
- Duration of analysis
- Distance and angle between illumination source and the camera

Kumar, M. et al. Distance PPG: Robust non-contact vital signs monitoring using a camera. Biomedical optics express. 2015

Poh et al. "Non-contact, automated cardiac pulse measurements using video imaging and blind source separation," Opt. Express 18, 10762-10774 (2010);
Heart Rate Variability

- HRV detected from an ECG and the mobile phone camera were shown to agree favorably.
- But less reliable due to its vulnerability to motion artifacts.
- Conditions such as arrhythmia has been reported to be identified with accuracy of 90%
- Detection of human emotions
Respiration Rate

- Detected by camera based on the recording of skin color changes of subject’s visible video.
- Derived from pulse wave width (PWW).
- Can be derived from the different respiratory induced variation (amplitude, intensity and frequency) in PPG signal.
- Affected by motion and physiological variations and tachypnea.
- Camera based identifying pneumonia has got sensitivity and specificity of 89% and 73% *
- Thermal camera based RR

*Javadi M et al. Int J Infect Dis. 2006 Mar;10(2)
Oxygen saturation

Based on the principle of reflectance pulse oximetry.

Challenges faced by this method are:

- Motion artifact
- Calibration
- Angle changes caused by subject motion
- Spectrum of the incident illumination
- Region of interest chosen
- High correlation and accuracy for the range from 90 to 100% *


http://www.swharden.com/blog/images/2012/12/pulse-oximeter-wavelength.jpg
Blood pressure

- Smart phone camera can record blood pressure (BP) with an accuracy of 95-100%.
- Recorded from pulse transition time (PTT).
- Along with PPG it also needs ECG recording.
- Confounding factors – Vasomotor tone & pre-ejection period.
- Maximum error between the cuff method and the cuff less method was 14 mmHg.
- Systolic blood pressure was measured more accurately than diastolic blood pressure.

Utility of the Photoplethysmogram in Circulatory Monitoring Andrew Reisner, M.D.; Phillip A. Shaltis, Ph.D.; Devin McCombie; H Harry Asada, Ph.D.
Temperature

- Skin temperature behavior can be recorded with infrared thermographic imaging (IRTI).

- Correlation of IRT temperatures with the core temperature was significant but weak (r<0.45).

- Gender, age, and distance of measurement influence the accuracy of IRT temperature.

- No touch + forehead thermometer can get fast and precise temperature readings.

http://www.flir.com/flirone/content/?id=69369
http://www.catphones.com/en-gb/phones/s60-smartphone
http://www.brauntherms.com/
Practical Applications

CONSUMER GRADE/ WELLNESS

Ming-Zhe Poh, Affective Computing Group at the MIT Media Lab

Wize - Semeoticons


MEDICAL GRADE

Arrhythmia detection

senseglass

cardio

http://www.cardio.com/

cocooncam

Resp.eyer

ThermoScan
Conclusion

- Strong correlation between parameters derived from camera recordings and standard reference sensors under controlled settings.
- Democratized single sensor usable multi-parameter monitoring
- Motion, illumination, ambience, ROI dimensions remain as challenges
- SpO2, NIBP, temperature (not NIR/Thermal) need more studies
- Accuracy growing from consumer grade (wellness) to medical grade
- To start in wellness / specific clinical application
  - Static, point of care monitoring: health kiosk – Wize, Cardiio
  - Single parameter e.g. respiration rate ~ pneumonia @XRCI – Resp.eyer
  - HRV based arrhythmia screening
  - Baby wellness monitor ~ cocooncam

Physiological perspective (what to look and how to look) are going to be critical in this space