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NewbornCare RTD 2013

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UniversitätsSpital Zürich

Pipeline for real-time heart-rate estimation from video streams

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Motivations

In Switzerland, 9% of the infants are born prematurely and it is crucial to continuously monitor health signals such as the heart and respiratory rates. The current monitoring systems face some limitations:

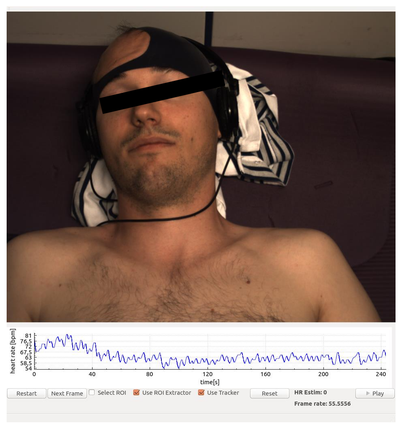
- They are prone to frequent body motion artifacts.
- They have a very high rate of false alarms (87.5%) sent to the nurses, leading to stressed and desensitized caregivers and discomfort for the neonates
- There is a lack of accurate **contactless technology.**

Region of Interest tracking and skin segmentation

Tracking

Segmentation

User interface

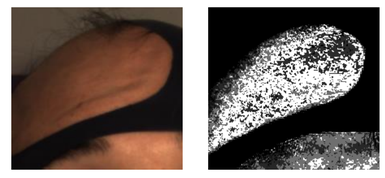


User interface shows ground-truth heart rate for testing (when available) as well as tracker options and video playback features

Tracking

Real-time feature detection tracking (based on the Struck algorithm) allows for a consistent extraction **over a long period of time** of the region where heart rate is extracted **despite movements** of the subject.

Segmentation



Segmentation is done by **backprojection** of a hue **histogram** (learned offline)

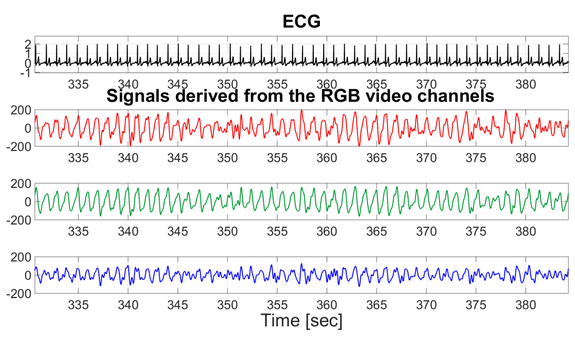
Color changes over time in the skin pixels carry information about the **heart rate**

The segmented region is then input into the heart rate estimation algorithm.

Heart rate estimation

Database and time series extraction

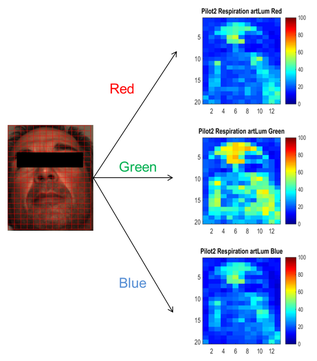
- **12 adult subjects**
- **46 4-minute video-sequences**
  - In visible light using a **RGB** camera
  - In the dark using a **NIR** camera an IR illumination
- In order to **induce changes in heart rate**, subjects were asked to perform:
  - Isometric **handgrip** exercise
  - **Modulation of the respiration** according to a given protocol
- The **ground-truth** heart rate was derived from the ECG acquired simultaneously with the video-sequences
- The **imaging photoplethysmographic (iPPG) signals were obtained by pixel averaging within the ROI, for each channel**. Example of signals:



What is the best location on the face to estimate heart rate?

A power spectral density analysis was carried out:

- For 6 video-sequences in visible light
- Using 10-second sliding window
- To compute the **percentage of the power at the local true heart rate**

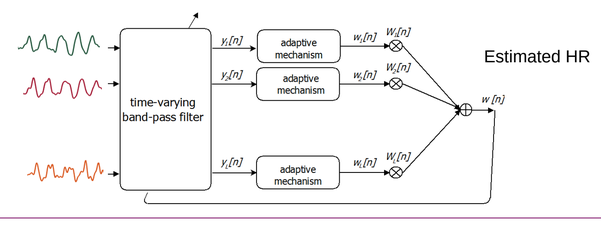


Conclusion: color fluctuations due to blood volume changes are more pronounced on the **forehead** and cheekbone regions. The **green channel** is the best one.

Method for real-time heart rate estimation

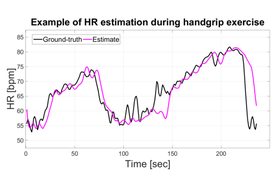
Adaptive frequency tracking:

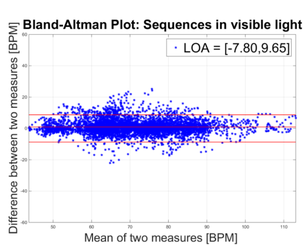
- Constantly updated **adaptive band-pass filter**
- Adaptive mechanism based on the oscillator equation
- Common instantaneous frequency component in **multiple-input signals** tracked using a weighting scheme



Preliminary results and conclusion

Performance		Real-time	Delay compensated
Visible	Average absolute error [bpm]	**3.14**	1.85
	Pearson correlation	0.93	0.94
	Approx. Delay [s]	4	0
	LOA 95% [bpm]	[-7.80 9.65]	[-6.59 8.50]
Dark	Average absolute error [bpm]	**4.21**	3.07
	Pearson correlation	0.86	0.89
	Approx. Delay [s]	4	0
	LOA 95% [bpm]	[-10.66 13.77]	[-9.51 12.66]





- These preliminary results on adult subjects are encouraging and prove that **heart rate can be estimated** using our video-setup.
- Moreover, the **HR fluctuations** induced by the modulation of the breathing rate or by the handgrip exercise **were correctly tracked**.
- iPPG based heart rate monitoring is possible both in **visible light and darkness** using near-infrared light.
- Suitable for **real-time applications.**

Next steps:

- Increase robustness against **motion artifacts**
- Validation of this processing scheme with **neonates**