DETECTING PULSE FROM HEAD MOTIONS IN VIDEO

CVPR 2013

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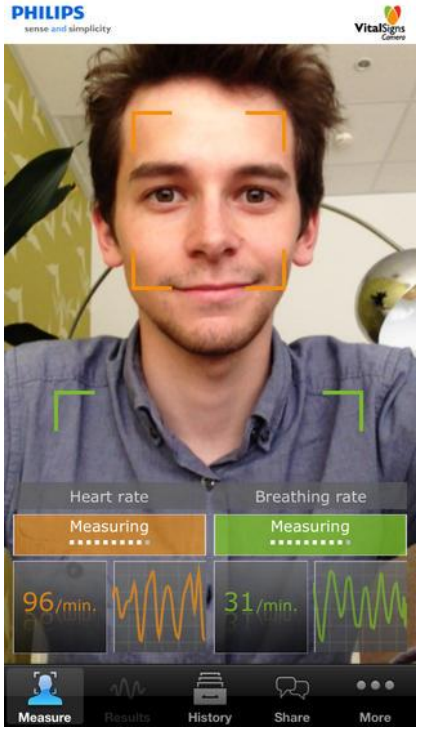
Motivation

- Diagnosis
  - Pulse rate → acute problems
  - Heat Rate Variability (HRV) → longer-term cardiac assessment
- Electrocardiogram (ECG)
  - Accurate, but…
  - Electrodes must be attached to the skin
- Doing it **non-invasively**
  - Premature newborns
  - Elderly
  - Long-term statistical analyses

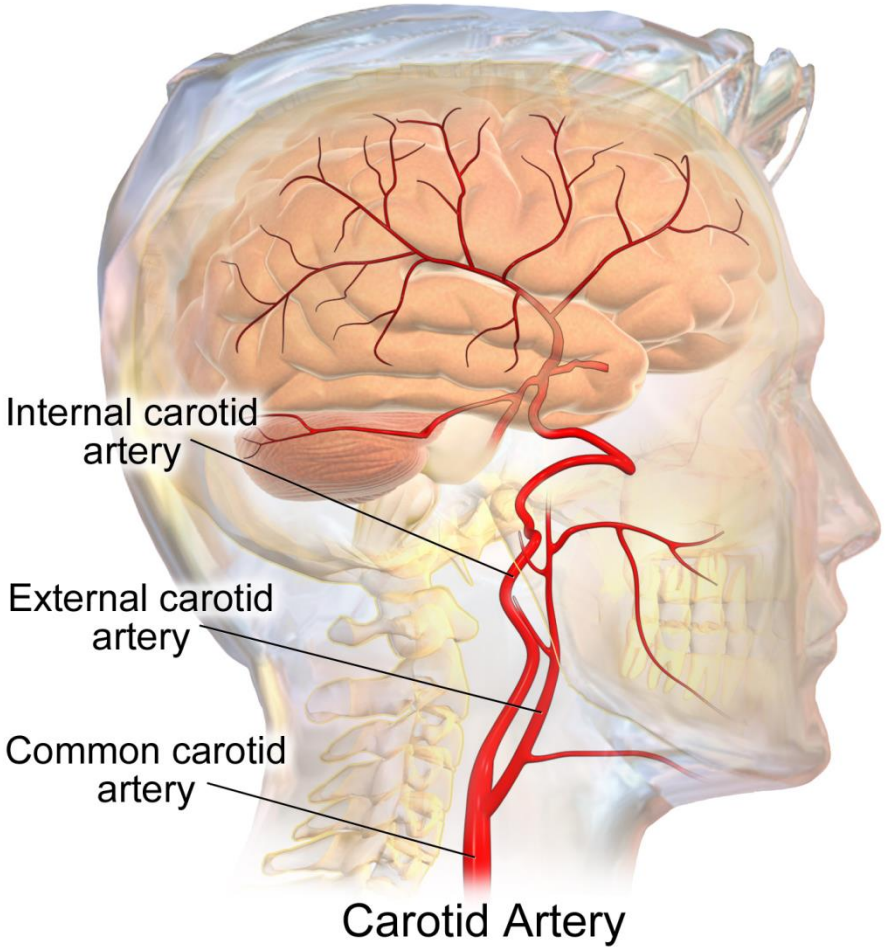
Previous works

- Color changes in the skin



→ Include **head motion** information!

Physiology

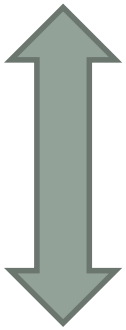


http://www.allinahealth.org/

Newton's Third Law

$F_{blood \rightarrow head} = F_{head \rightarrow blood}$

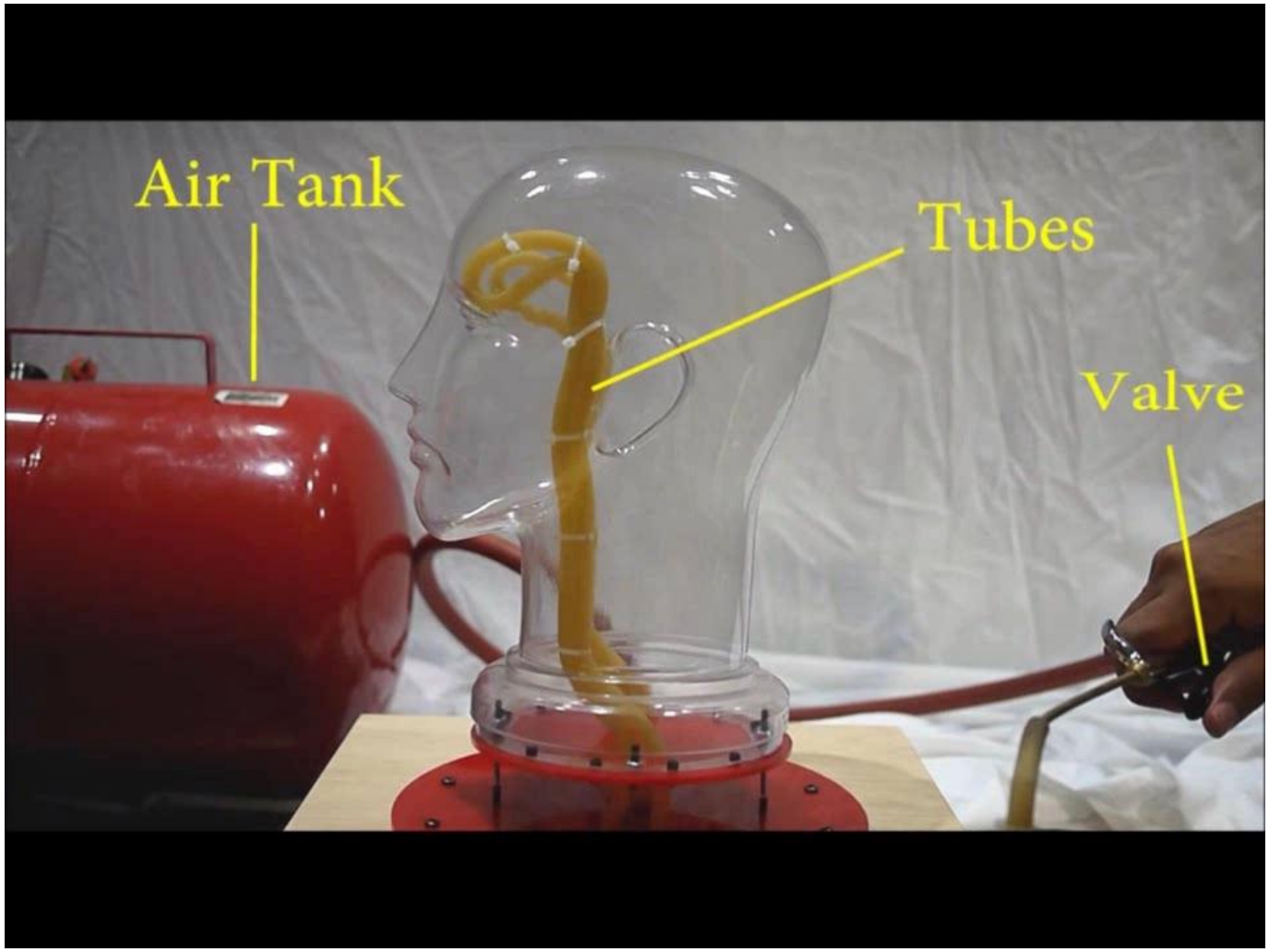
$F_{blood \rightarrow head}$



Head motions

Blood pumped to the head

Physiology (2)



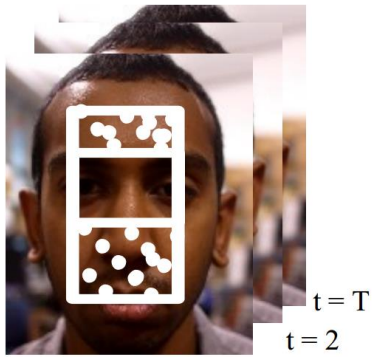
Physiology (3)

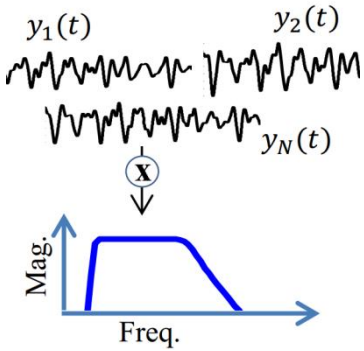
Eulerian Video Magnification (MIT CSAIL 2012)

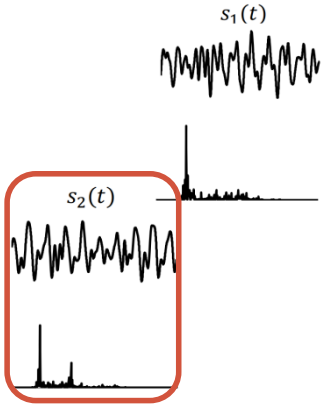
Input Video

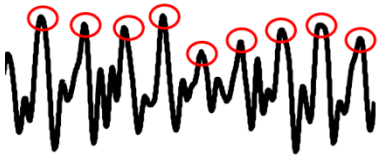
Method

- Whole framework





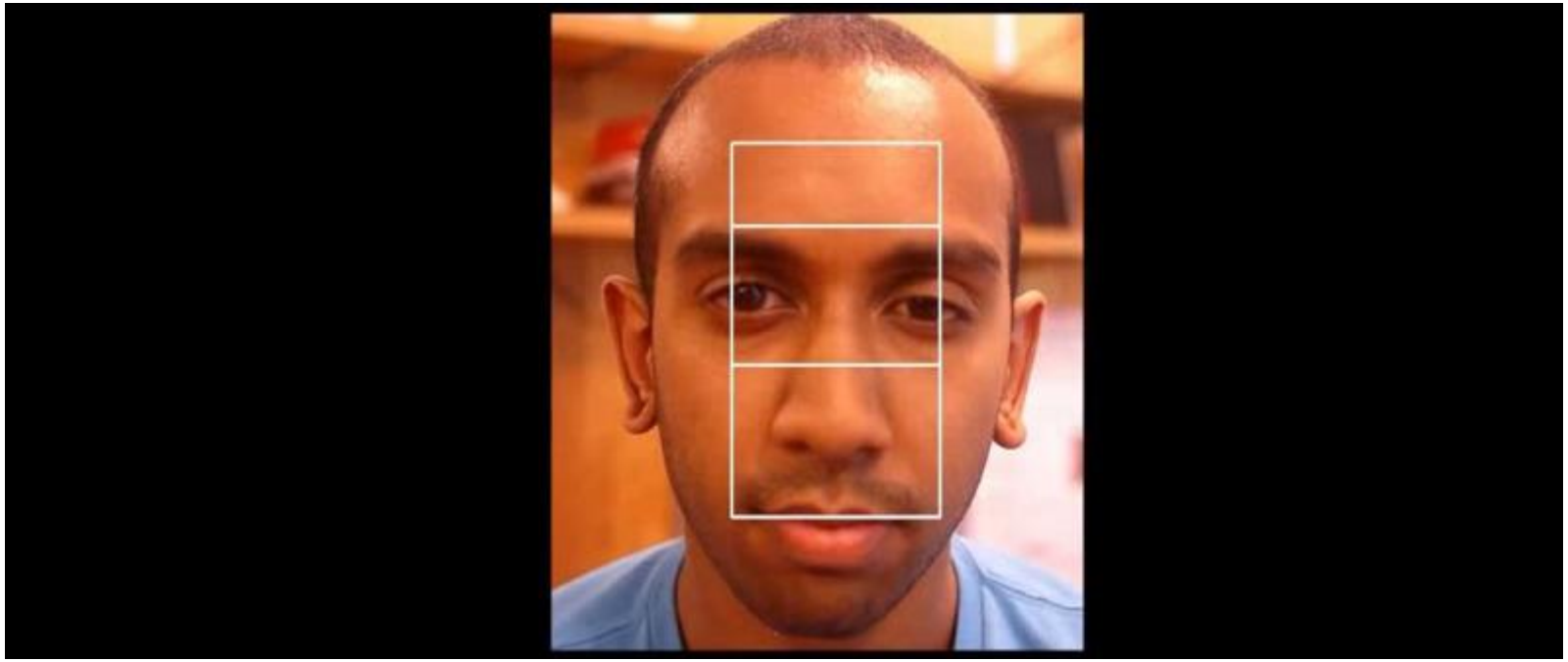




Region selection and feature tracking → Temporal filtering → PCA and signal selection → Peak detection

Method (2)

- Region selection and feature tracking
  - **Viola-Jones** face detector; remove the eyes
  - **Lucas-Kanade** tracker; select stable feature points



Method (3)

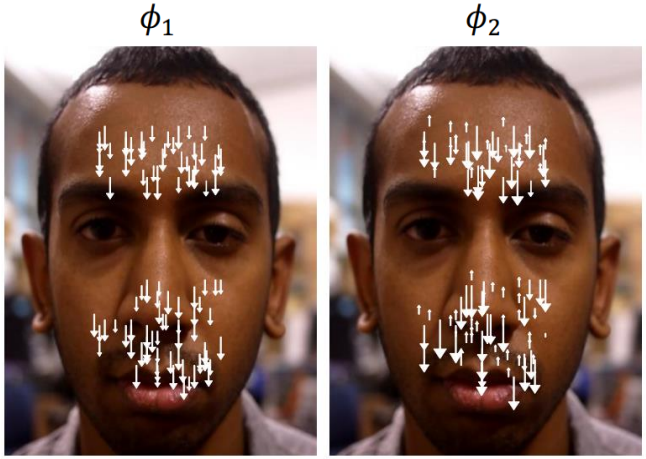
- Temporal filtering
  - 5th order butterworth bandpass filter: **[0.75, 5] Hz**

- PCA decomposition

$$m_t = [y_1(t), y_2(t), \cdots, y_N(t)]$$

$$\Sigma_m = \frac{1}{T}\sum_{i=1}^{T}(m_t - \bar{m})(m_t - \bar{m})^T$$

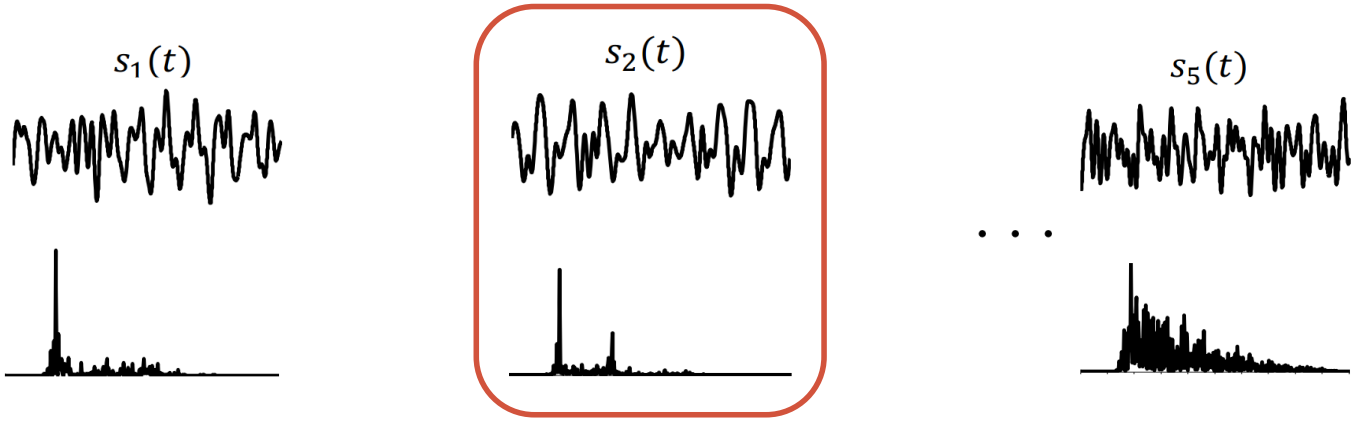
$$\Sigma_m \Phi_m = \Phi_m \Lambda_m$$



$$s_i(t) = \begin{pmatrix} m_1 \\ m_2 \\ \vdots \\ m_T \end{pmatrix} \cdot \phi_i$$

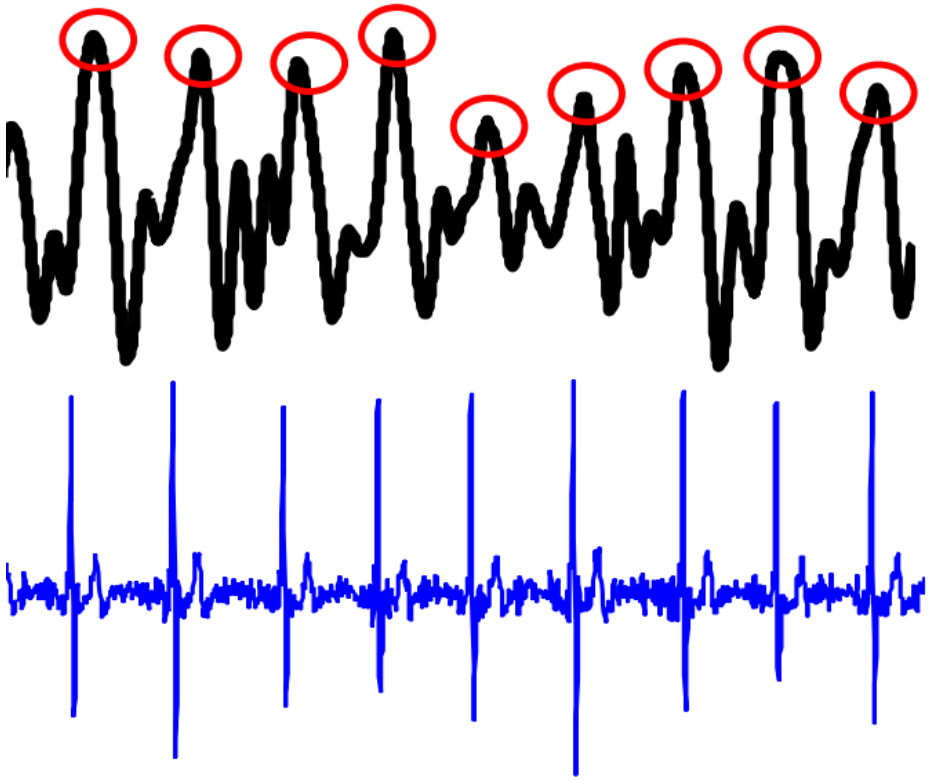
Method (4)

- Signal selection
  - Choose component that is **most periodic**
    - Analyze frequency content



Method (5)

- Peak detection
  - Largest value in a sample-centered window

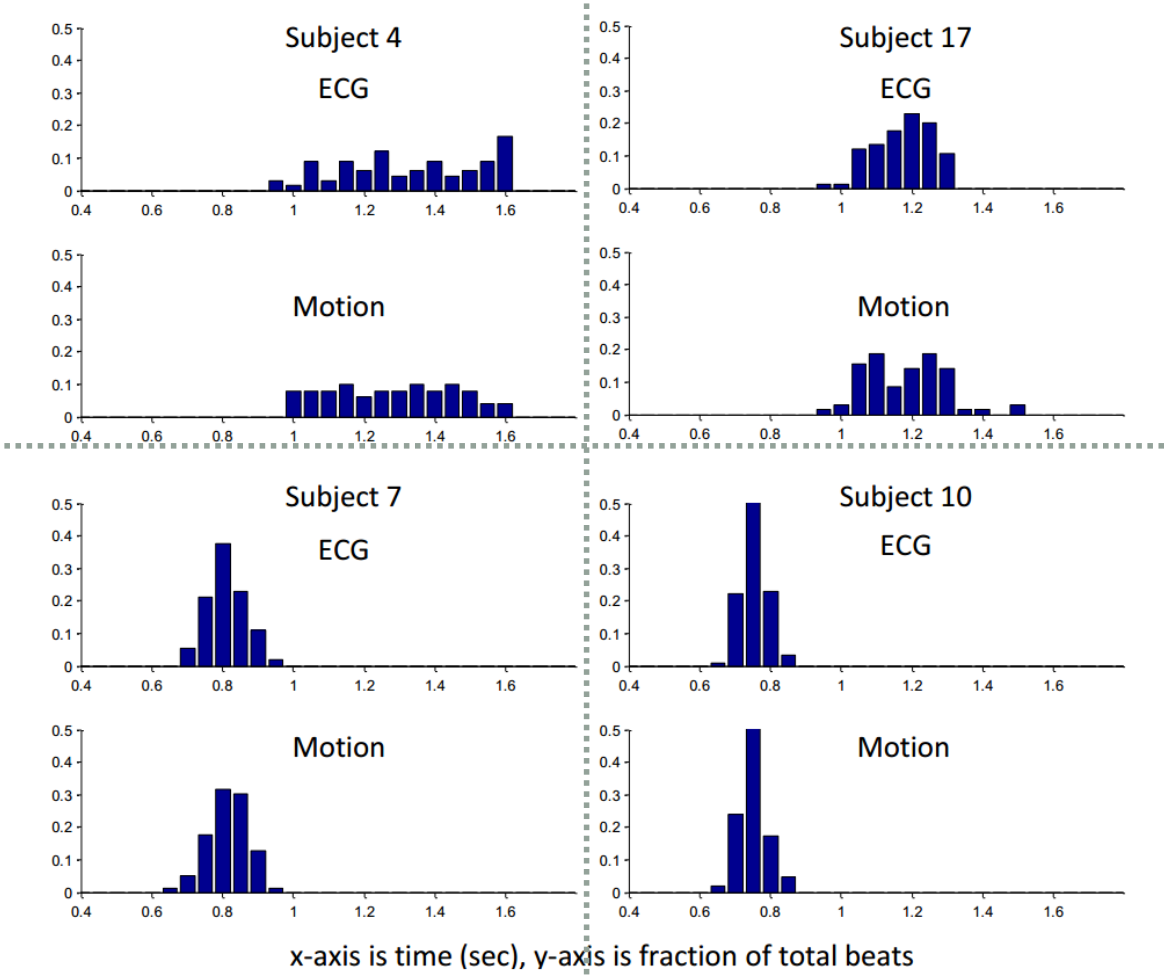


ECG ground truth

Results – Pulse rate

	Avg. Pulse (beats per minute)		Number of peaks	
Sub.	ECG	Motion (% error)	ECG	Motion(% error)
1	66.0	66.0(0)	99	98(1.0)
2	54.7	55.3(1.1)	82	84(2.4)
3	81.3	82.6(1.6)	122	116(4.9)
4	44.7	46.0(2.9)	67	70(4.5)
5	95.3	96.0(0.7)	143	142(0.7)
6	78.9	78.0(1.1)	92	78(15.2)
7	73.3	71.3(2.7)	110	100(9.1)
8	59.3	58.6(1.2)	89	88(1.1)
9	56.7	58.6(3.4)	85	84(1.2)
10	78.7	79.3(0.8)	118	117(0.8)
11	84.7	86.6(2.2)	127	121(4.7)
12	63.3	62.6(1.1)	95	95(0)
13	59.3	60.0(1.2)	89	89(0)
14	60.0	61.3(2.2)	90	89(1.1)
15	80.0	81.3(1.6)	120	114(5.0)
16	74.7	74.6(0.1)	112	110(1.8)
17	50.0	49.3(1.4)	75	76(1.3)
18	77.1	78.8(2.2)	90	85(5.6)

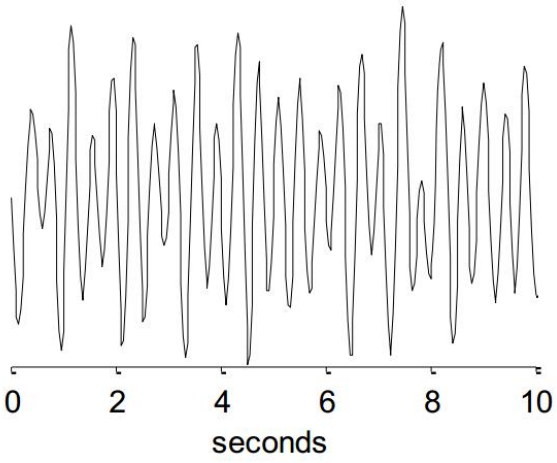
Results – Beat length

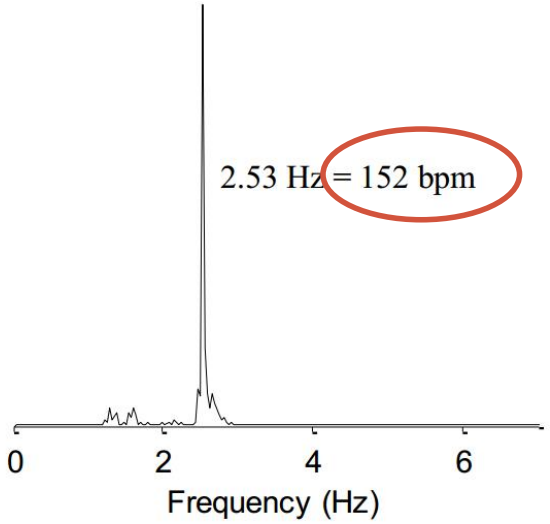


Sub.	ECG $\mu(\sigma)$	Motion $\mu(\sigma)$	KS-Test p-value
1	0.91(0.06)	0.90(0.06)	0.89
2	1.08(0.08)	1.06(0.11)	0.52
3	0.73(0.04)	0.73(0.08)	0.05
4	1.34(0.19)	1.28(0.18)	0.14
5	0.62(0.03)	0.63(0.07)	<0.01
6	0.76(0.04)	0.76(0.04)	0.64
7	0.81(0.05)	0.81(0.06)	0.85
8	1.01(0.04)	1.02(0.09)	0.16
9	1.04(0.07)	1.04(0.11)	0.27
10	0.75(0.04)	0.75(0.04)	0.75
11	0.70(0.06)	0.70(0.08)	0.30
12	0.94(0.08)	0.94(0.09)	0.85
13	0.99(0.04)	0.98(0.12)	<0.01
14	0.99(0.11)	0.98(0.12)	0.47
15	0.74(0.05)	0.75(0.06)	0.95
16	0.80(0.05)	0.80(0.06)	0.60
17	1.18(0.08)	1.18(0.11)	0.70
18	0.76(0.05)	0.76(0.06)	0.24

Results – Applications

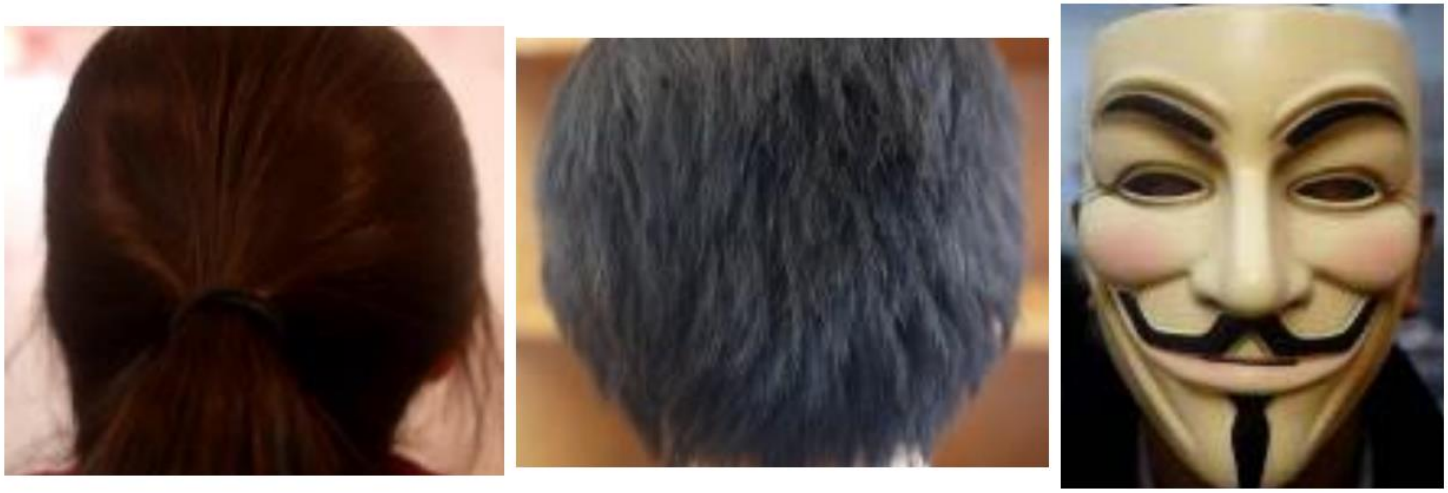
- Newborn monitoring





Results – Applications (2)

- Hidden faces
  - No need for the skin to be visible (unlike color-based approaches)



Discussion

- **Accurate** pulse and beat rate measurements

- Limitations
  - Only **healthy** individuals tested
  - Camera's **sampling rate** (<< ECG) and **acquisition time**
  - Pulse **variability** from the aorta to the head
  - **Lighting** conditions

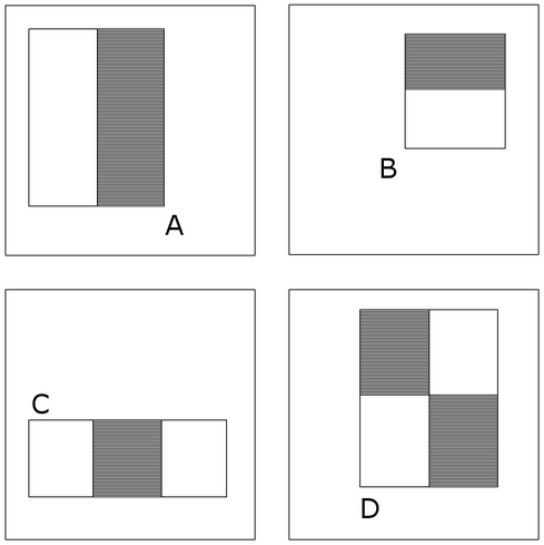
- Possible future improvements
  - Filtering to account for **macroscopic head movements**
  - Other motion-derived cardiac metrics?
  - Combine **motion and color** information

Thank you!

http://newsoffice.mit.edu/2013/seeing-the-human-pulse-0620

Extra slides – Viola Jones

- Haar-like features
  - Integral image



- AdaBoost (feature selection)

- Cascade of classifiers (focus on positive windows)

Extra slides – Lucas-Kanade

- Optical flow equation (brightness constancy assumption)

$$I_x(x,y) \cdot u + I_y(x,y) \cdot v = -I_t(x,y)$$

  - One equation, two unknowns (*aperture problem*)

- Use pixel neighborhood (assume displacement is the same)

- Least-squares minimization