Time-Varying Behavior of Motion Vectors in Vection-Induced Images In Relation to Autonomic Regulation

Tohru Kiryu[1], Hiroshi Yamada[1], Masahiro Jimbo[1], and Takehiko Bando[2]

[1]Graduate School of Science and Technology,
[2]Graduate School of Medical and Dental Sciences,
Niigata University, Niigata, Japan

Abstract—**Virtual reality (VR) is a promising technology in biomedical engineering, but at the same time enlarges another problem called cybersickness. Aiming at suppression of cybersicknes, we are investigating the influences of vection-induced images on the autonomic regulation quantitatively. We used the motion vectors to quantify image scenes and measured electrocardiogram, blood pressure, and respiration for evaluating the autonomic regulation. Using the estimated motion vectors, we further synthesized random-dot pattern images to survey which component of the global motion vectors seriously affected the autonomic regulation. The results showed that the zoom component with a specific frequency band (0.1 – 3.0 Hz) would induce sickness.**

Keywords—**cybersickness, autonomic regulation, motion vector, vection-induced image, random-dot pattern**

Background

-Development of digital imaging technology is producing many image formats, resolutions, frame rates, in addition to conventional factors.

-Current digital imaging technology is also creating extraordinary special effects that we have never seen or experienced.

- Contrary to the benefits, digital imaging technology is widely spreading unexpected visual stimulus.

-Not only entertainment, but also practical problems are emerging especially in the virtual reality (VR) or the virtual environment (VE).

-Regarding visually induced illusions of self-motion, it has been reported that the mismatch between visual system and vestibular system causes sickness (sensory conflict theory) .

Cybersickness

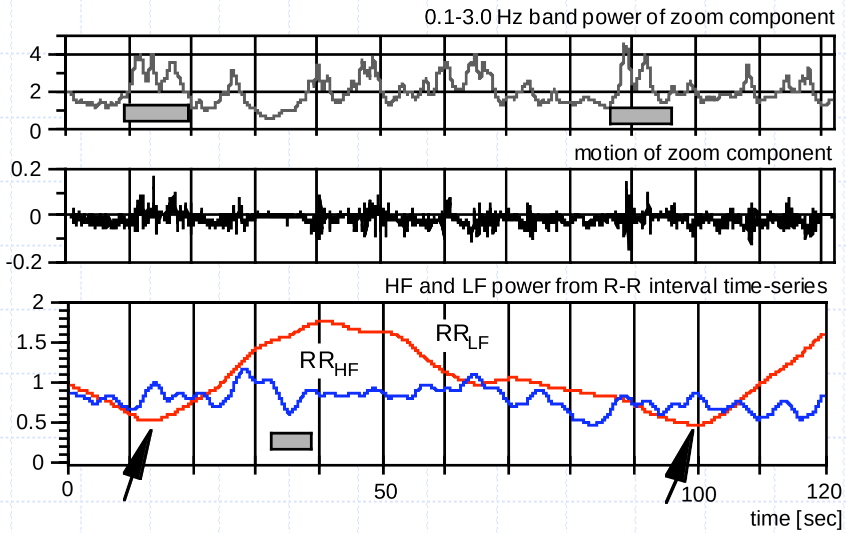
Approaches

1. Database of Biosignals under Vection-Induced Images

2. Quantifying the Image Components by Motion Vectors

3. Featuring Motion Vectors around Sickness Intervals that were Determined by Biosignals.

4. Estimation of System Function by Multivariate ARX Model

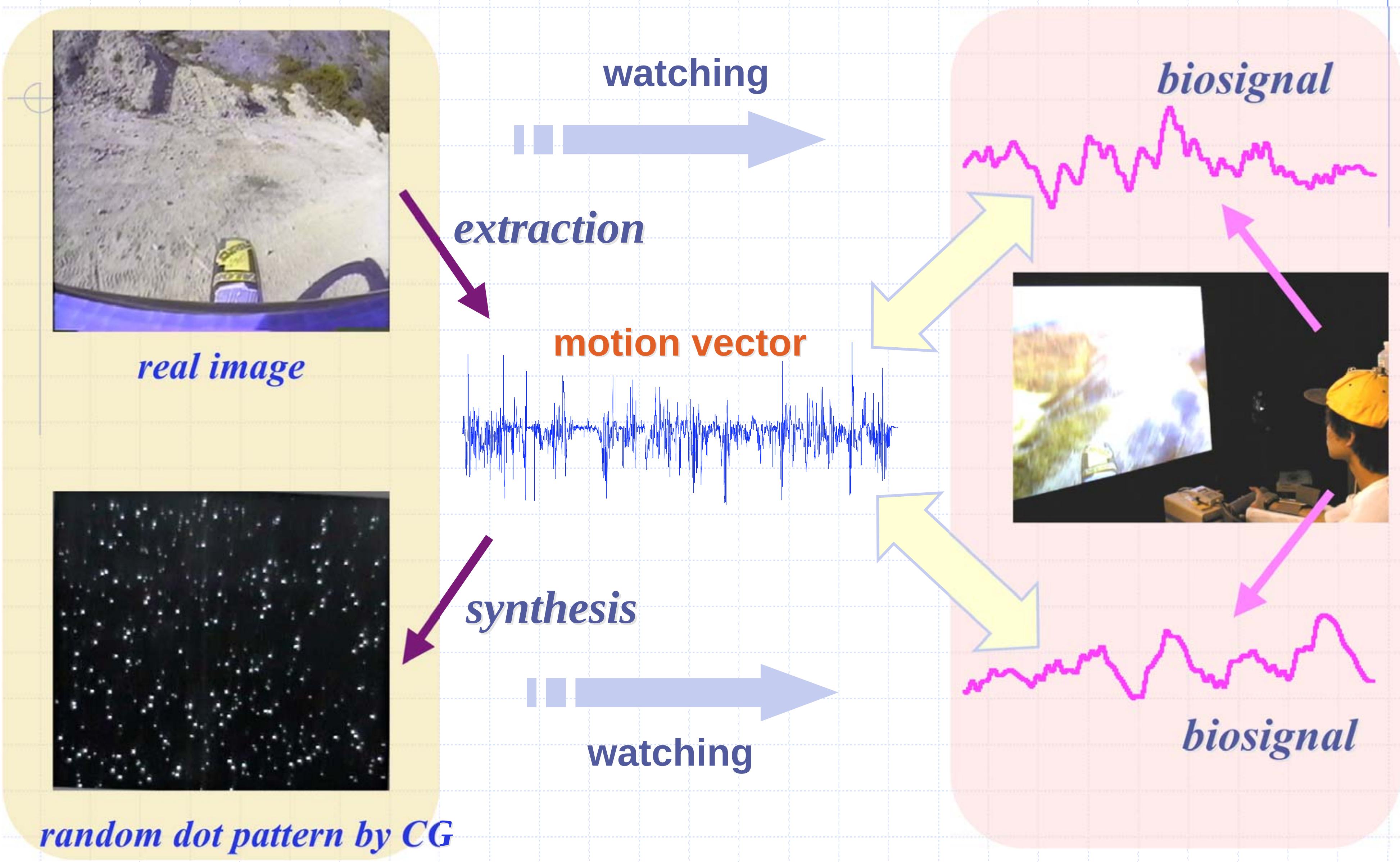


Band power of zoom component

zoom component

HF & LF power of R-R interval

Overview



watching
biosignal
extraction
real image
motion vector
synthesis
watching
biosignal
random dot pattern by CG

Experiments under Real & RDP Images

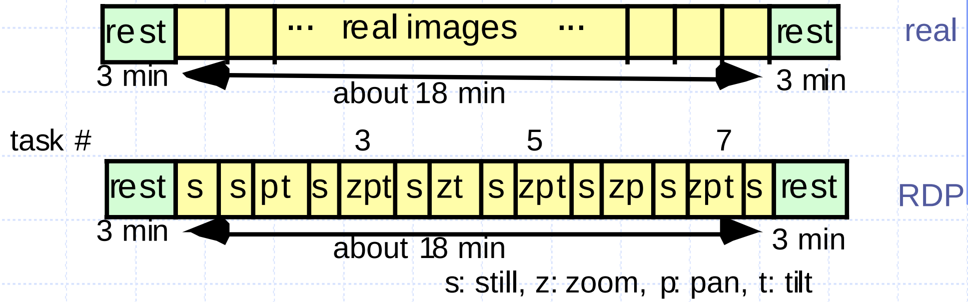
real images Vehicle experiencing video

Parachute
Bobsleigh
boat
Go cart
Hang glider
Mountain-bike
Car race
Bungee jump
diving
Bike race



at Niigata University（December, 2002）

Experimental Protocol



Subjects

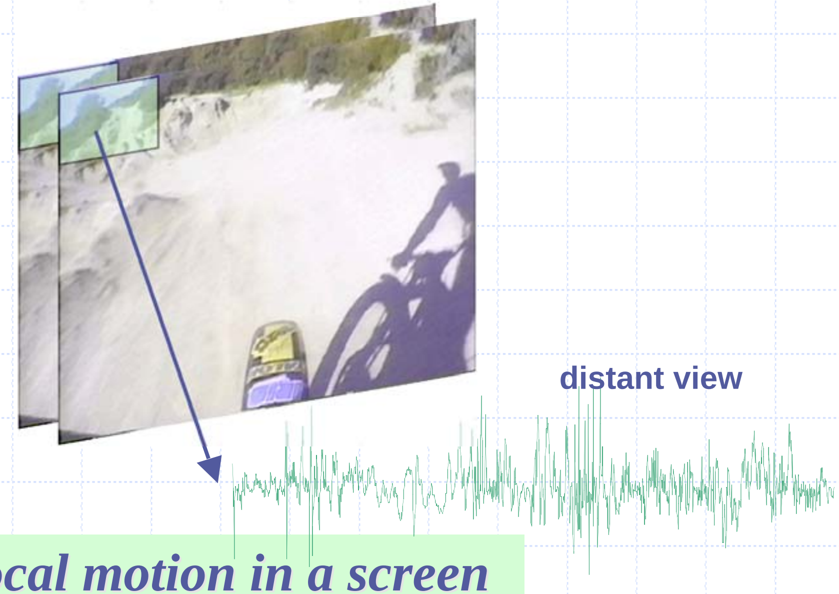
ten healthy young subjects (eight males and two female from 21 to 24 yrs. old)

Measured Biosignals

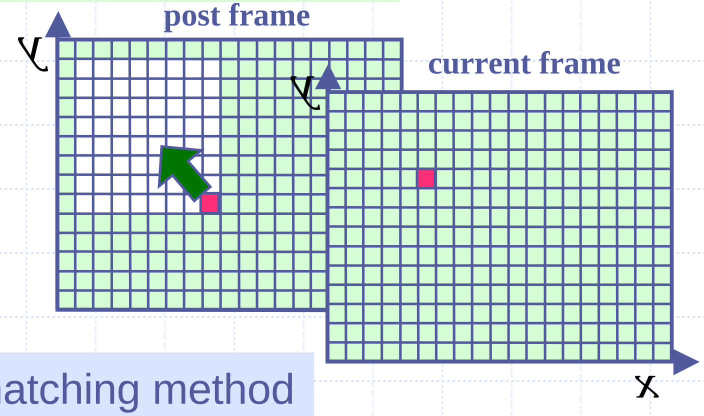
ECG: chest
Respiration: tube sensors around the chest and the abdomen
Blood Pressure: tonometry method

Quantification of Image by Motion Vectors

Local Motion Vector

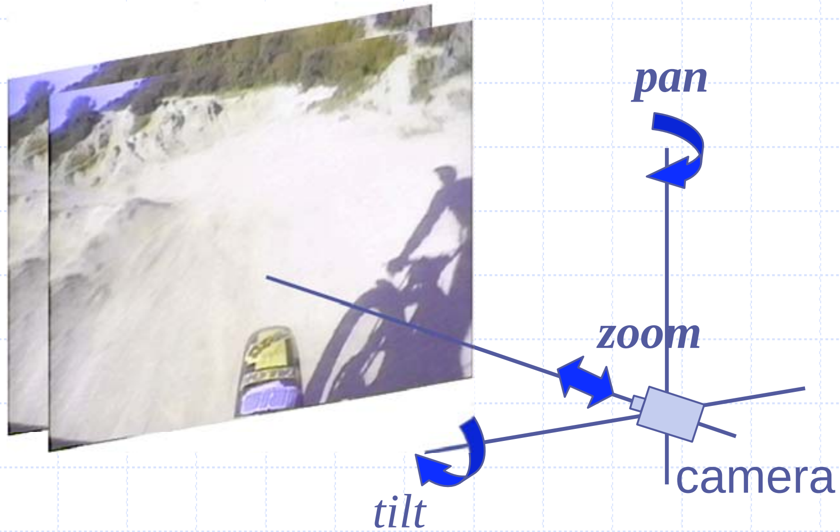


local motion in a screen

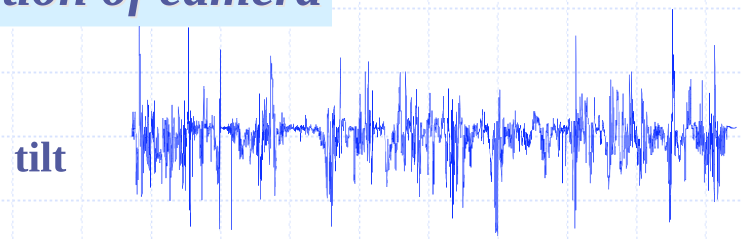


Block matching method

Global Motion Vector

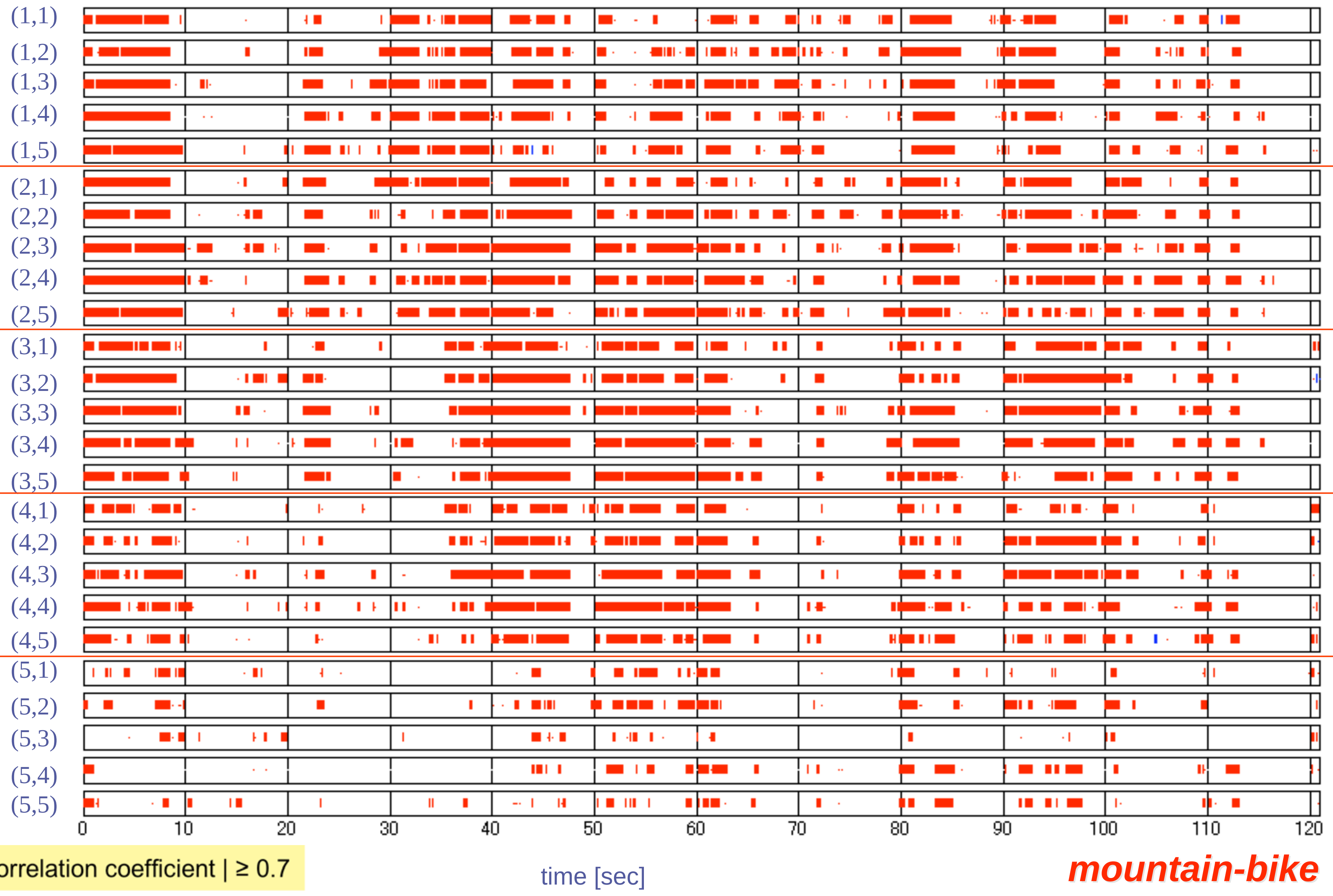


motion of camera



Bottom up approach

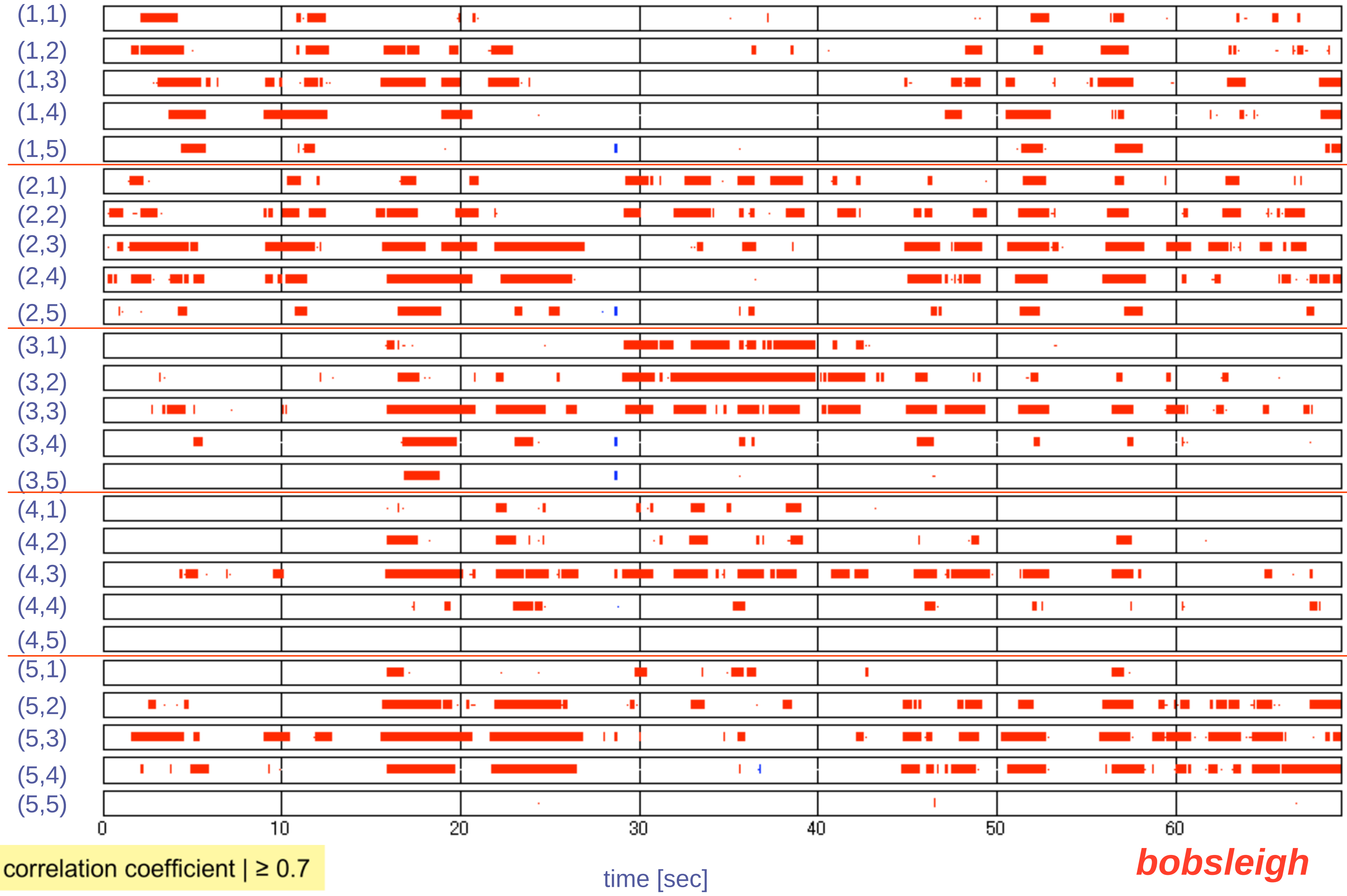
Correlation between Pan and Right/Left



| correlation coefficient | ≥ 0.7

mountain-bike

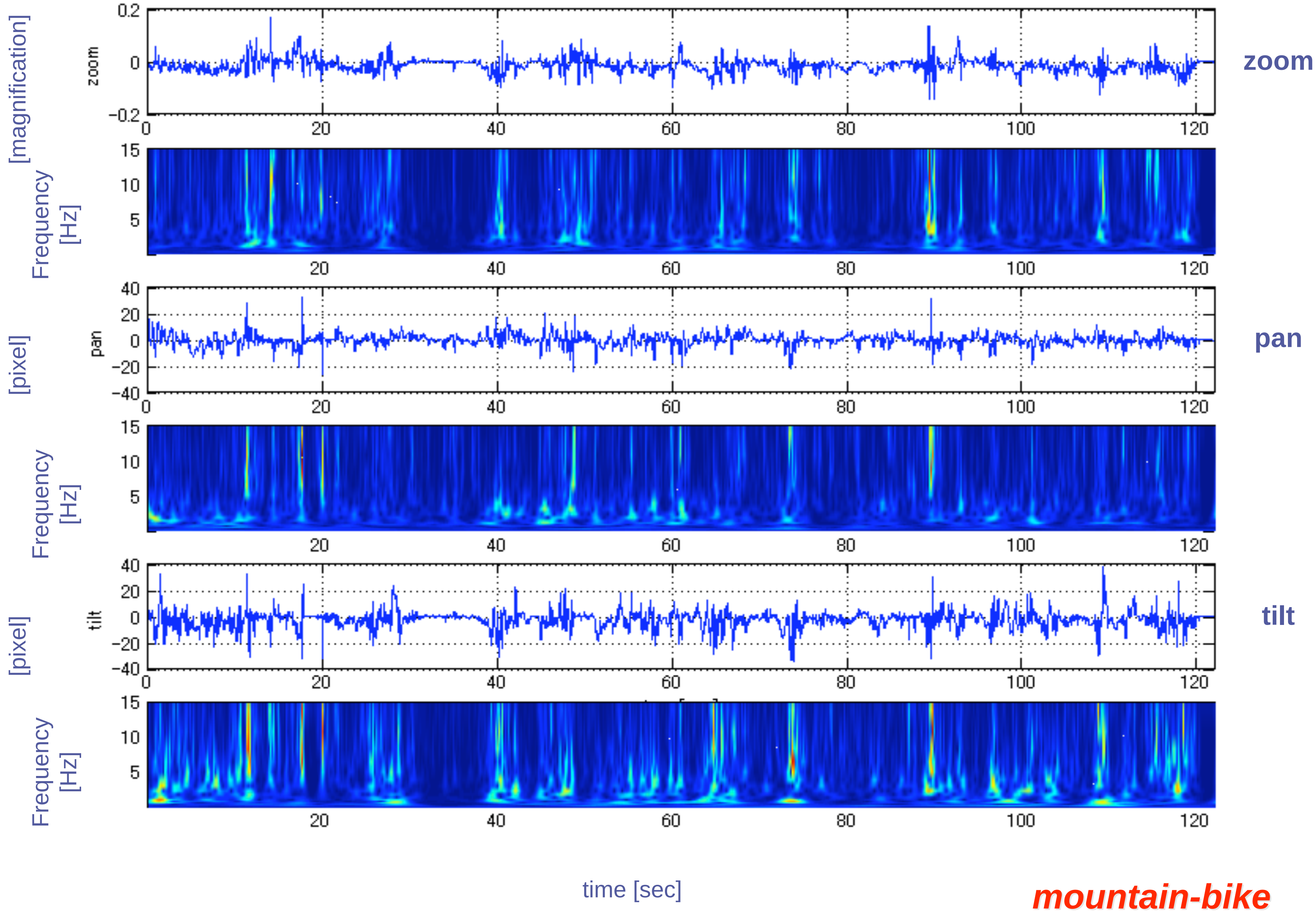
Correlation between Pan and Right/Left



| correlation coefficient | ≥ 0.7

bobsleigh

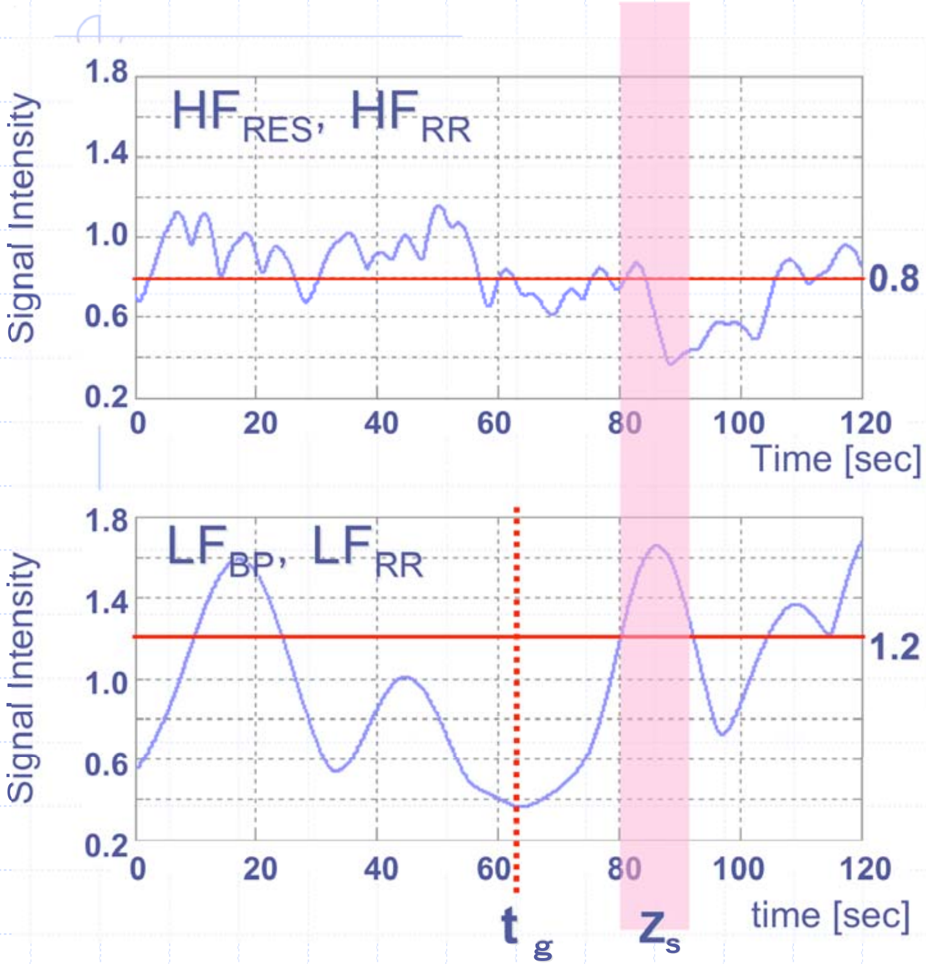
GMV and Time-Frequency Representation



mountain-bike

Sickness Interval and Trigger Point

☆ Estimation of Trigger Points



HF_{RES}, HF_{RR} (Respiration, HRV)

LF_{BP} , LF_{RR} (Blood Pressure, HRV)

⇩

Normalized data by values during 3-min rest

Sickness Interval Z_s

- $(HF_{RES\_80\%} \cap LF_{BP\_120\%}) \subset LF_{BP\_120\%}$
- $(HF_{RR\_80\%} \cap LF_{RR\_120\%}) \subset LF_{RR\_120\%}$

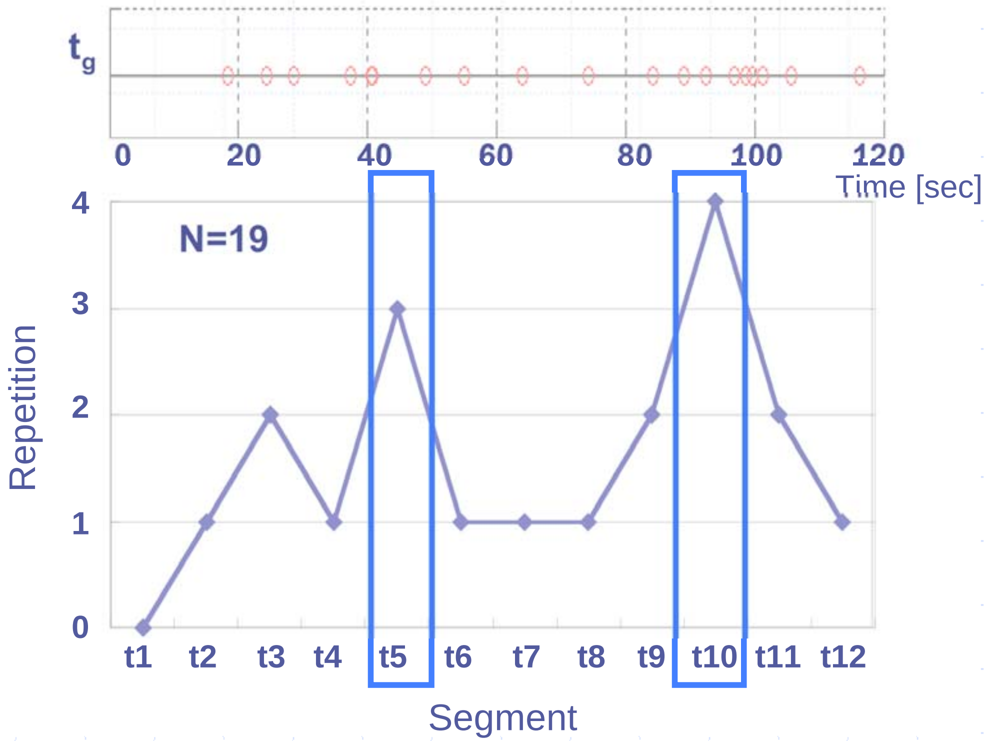
Trigger Point t_g

- local minimum of LF_{BP}
- local minimum of LF_{RR}

Distribution of Trigger Points

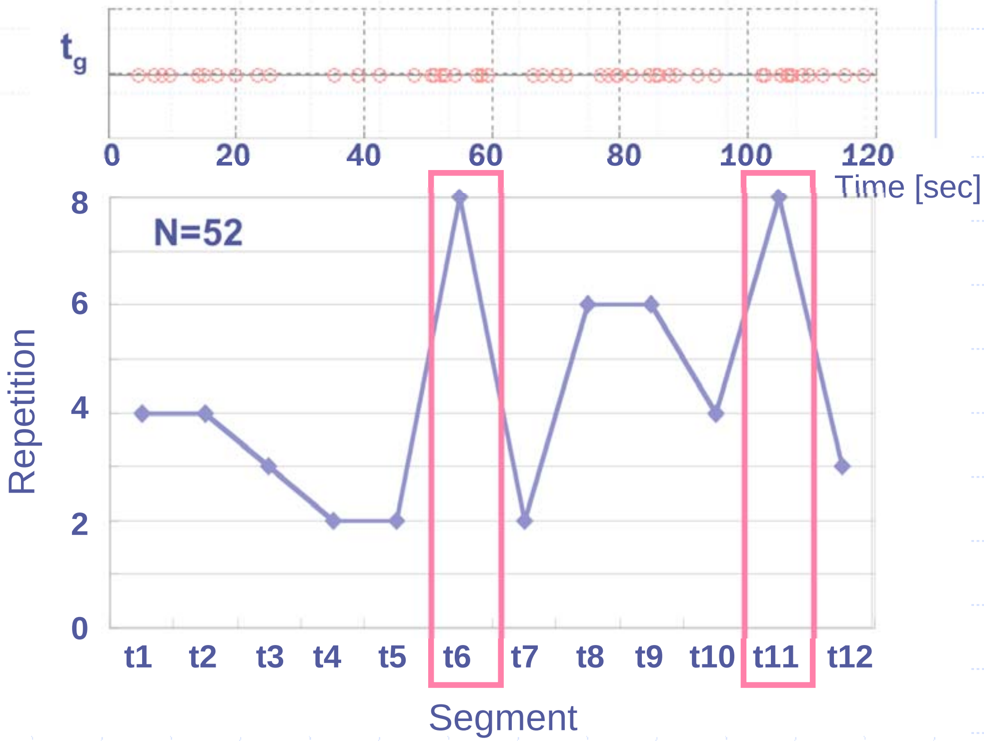
★ Trigger Points t_g as a function of time

- real image (mountain bike)



t_g= 41, 49, 93, 99 [sec]

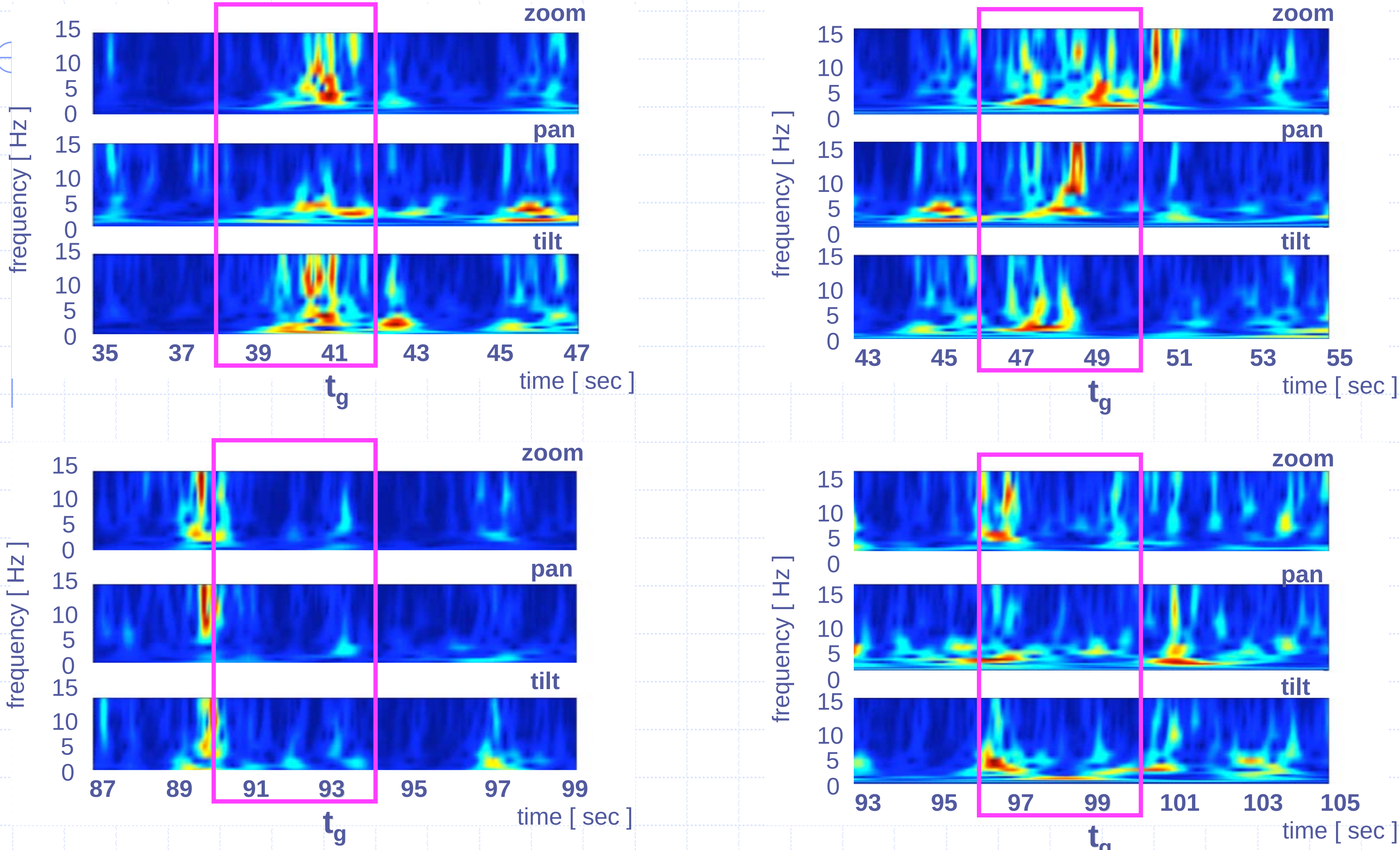
- random dot pattern image



t_g= 50, 59, 103, 110 [sec]

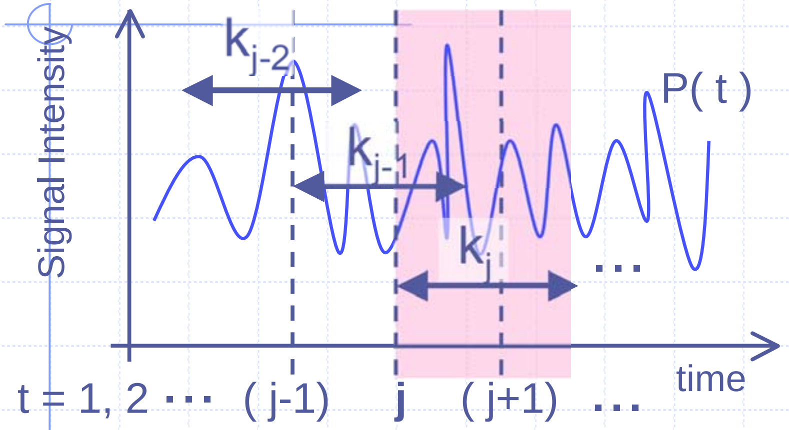
t1:1-10 [sec], t2:11-20 [sec], t3:21-30 [sec], t4:31-40 [sec], t5:41-50 [sec], t6:51-60 [sec], t7:61-70 [sec], t8:71-80 [sec], t9:81-90 [sec], t10:91-100 [sec], t11:101-110 [sec], t12:111-120 [sec]

Time-Frequency Structure of GMVs at Trigger Points



Extraction of Trigger GMV by Similarity

☆ Survey for Similar Time-Frequency Structure



MV(t): GMV (zoom, pan, tilt)

↓ ***Wavelet Transform***

Power of MV

$$P(t) = \sum_{i=1}^{n} \sqrt{(\mathrm{Re}\{MV(f_i,t)\})^2 + (\mathrm{Im}\{MV(f_i,t)\})^2}$$

f : frequency, t : time

- frequency band: 0.01- 15 [Hz]
  (n. of bands, n = 31)

-mP(t): mean of Power
  for each section (k_1, k_2, ···, k_j, ···)

- interval: 3 [sec] (90 [point])
- shift: 1 [sec] (30 [point])

$$\boldsymbol{V_0} = (\, mP_{zoom},\ mP_{pan},\ mP_{tilt}\,)$$

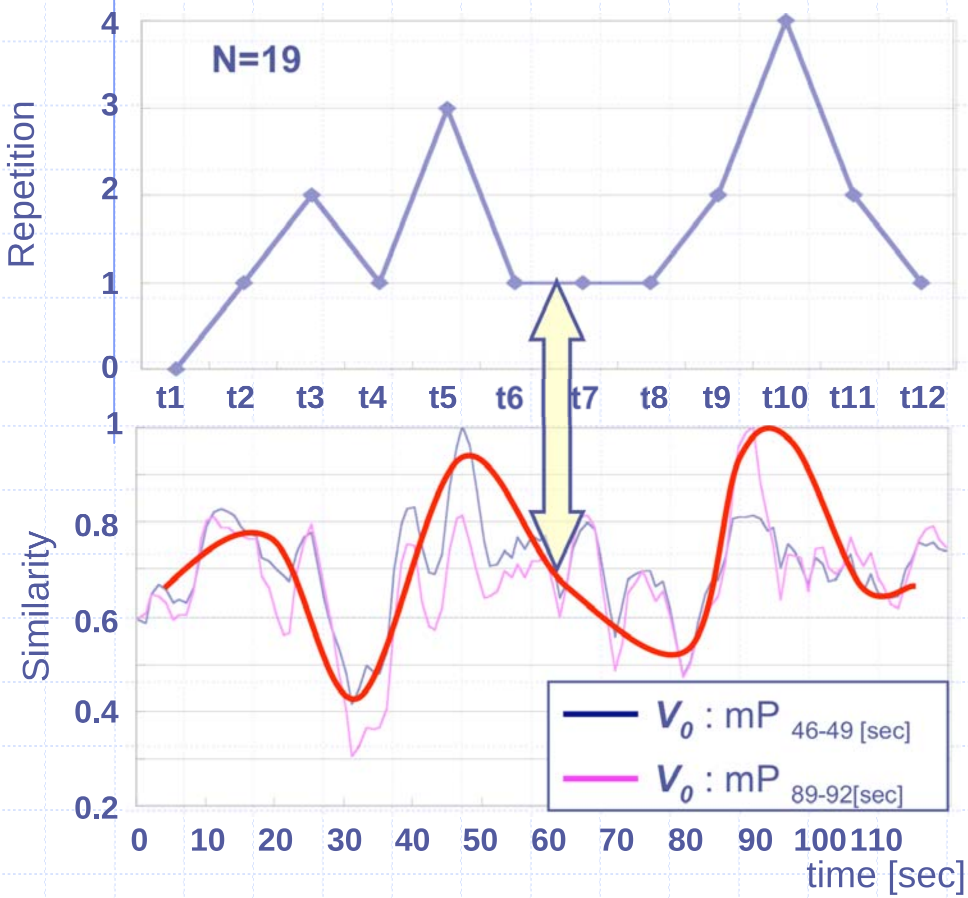
$$\boldsymbol{V(t)} = \{mP_{zoom}(t),\ mP_{pan}(t),\ mP_{tilt}(t)\}$$

Similarity $$\sigma(t) = \cos^2\left[\frac{(\boldsymbol{v_0}\cdot\boldsymbol{v})}{\|\boldsymbol{v_0}\|\cdot\|\boldsymbol{v}\|}\right]$$

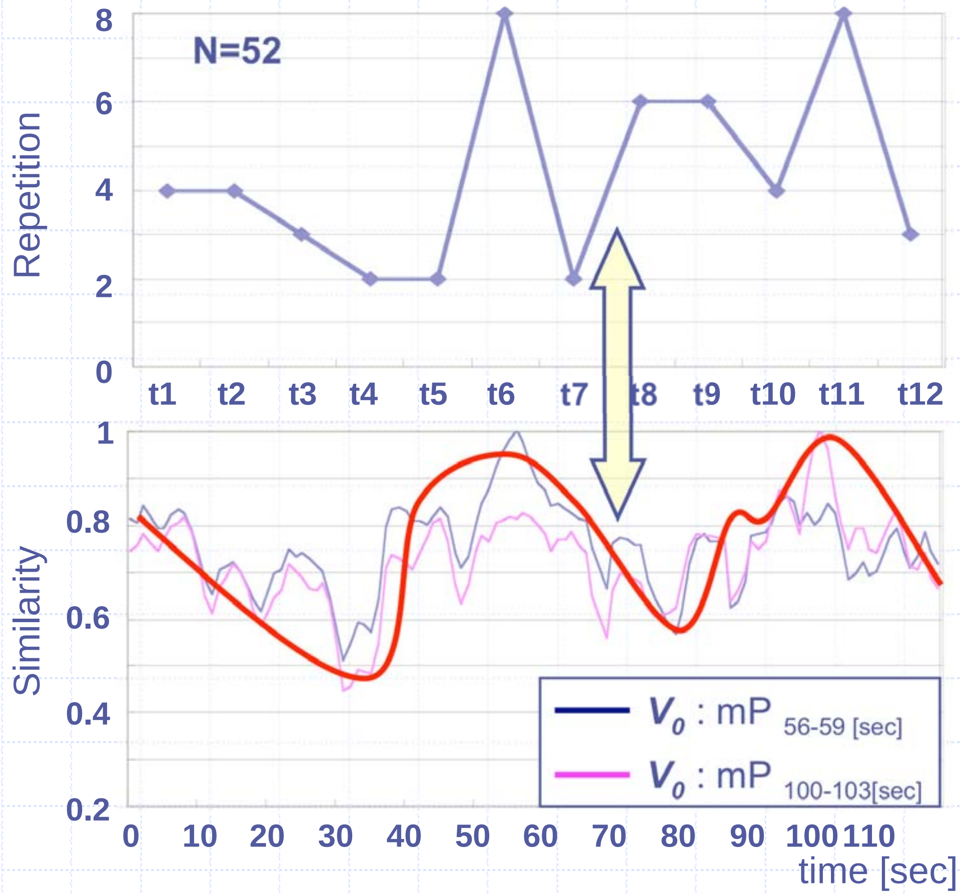
Distribution of Trigger Points and Similarity of GMV

☆ Comparison between biosignal-related index and GMV-related index

- real image (mountain bike)



- random dot pattern image



Looks similar !

Conclusion

-We studied influences of vection-induced images in the relationships between autonomic nervous activity related indices and motion vectors of images.

-Autonomic nervous activity was evaluated from R-R interval, blood pressure, and respiration. The motion vectors including global and local motion vectors were estimated by the data compression technique.

-According to the time-varying behavior of motion vectors, the temporal high-frequency (over 3 Hz) with steady low-frequency of GMVs possibly caused cybersickness.

-Similarity function of GMV showed a similar behavior of the number of trigger points as a function of time.

Cybersickness could be predicted by the similarity function of GMV

- However, we have not yet concluded whether the unpleasant feeling was caused by the content of the vection-induced image or the structure of the image scene (the frame rate, the vibration of objects, etc).