# Influence of Vection-Induced Images on Autonomic Regulation Evaluated by Time-Varying Behavior of Motion Vectors

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*Abstract*—**Virtual reality (VR) is promising technology, but at the same enlarges another problem called cybersickness. Aiming at suppression of cybersicknes, we are investigating the influences of vection-induced images on autonomic regulations quantitatively. Using estimated motion vectors, we further synthesized random-dot pattern images as contents-free images. In a test by synthesized images, we surveyed which component of the global motion vector seriously affected the autonomic regulation. The results showed that the zoom component would induce sickness and under unpleasant situation the time-frequency representation of motion vectors revealed the switching behavior of a dominant vibration frequency that was related to camera work. We finally demonstrated the system function approach by the multivariable ARX model and successfully correlated the global motion vectors and the low-frequency power of blood pressure. As a result, the system function approach will benefit to predict the levels of cybersickness for individuals.**

*Keywords*—**cybersickness, autonomic regulation, motion vector, vection, multivariable ARX model**

# Approaches

１．**Database of Biosignals affected by Vection-Induced Images**：映像生体影響の出現が確認されている映像に対し，生体信号でみられた特徴のデータベース化

２．**Featuring the Components of Image by Motion Vectors**：動きベクトルによる映像要素の特徴づけ

３．**Analysis by Synthesized Images**：映像要素を様々に変えたシミュレーション映像を制作し，映像生体影響を解析

４．**Estimation of System Function by Multivariate ARX Model**：映像の動きベクトルを入力とし、自律神経系の概周期的な生体信号（心拍変動や呼吸波形、血圧波形など）を出力とする多変量ARXモデル推定

# Rating of Image（映像のレイティング）

## Strength of Unpleasant Impression under Vection-Induced Images

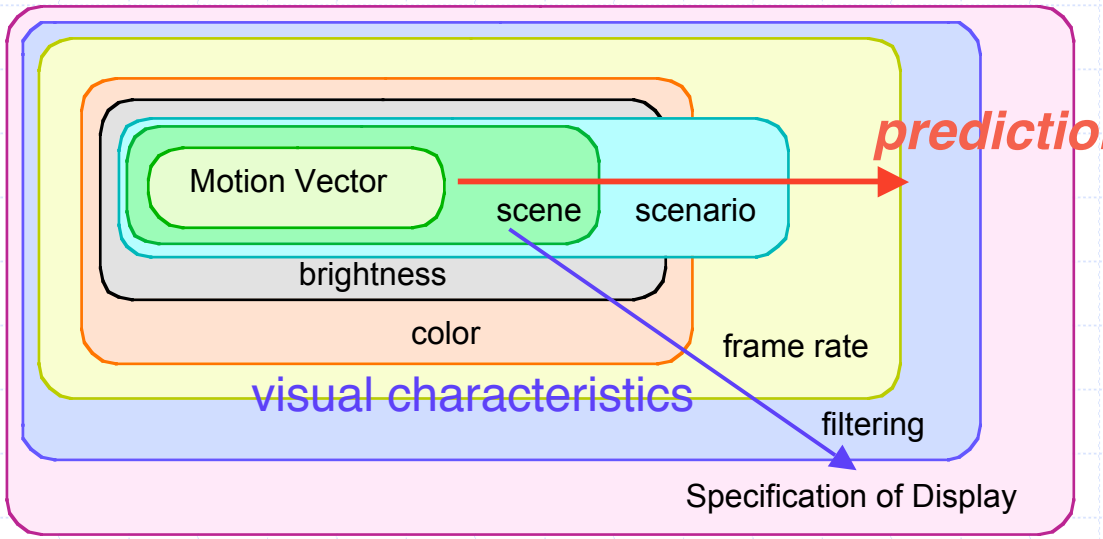
= (*prediction-required level for images*)

|| (*experience for image contents*)

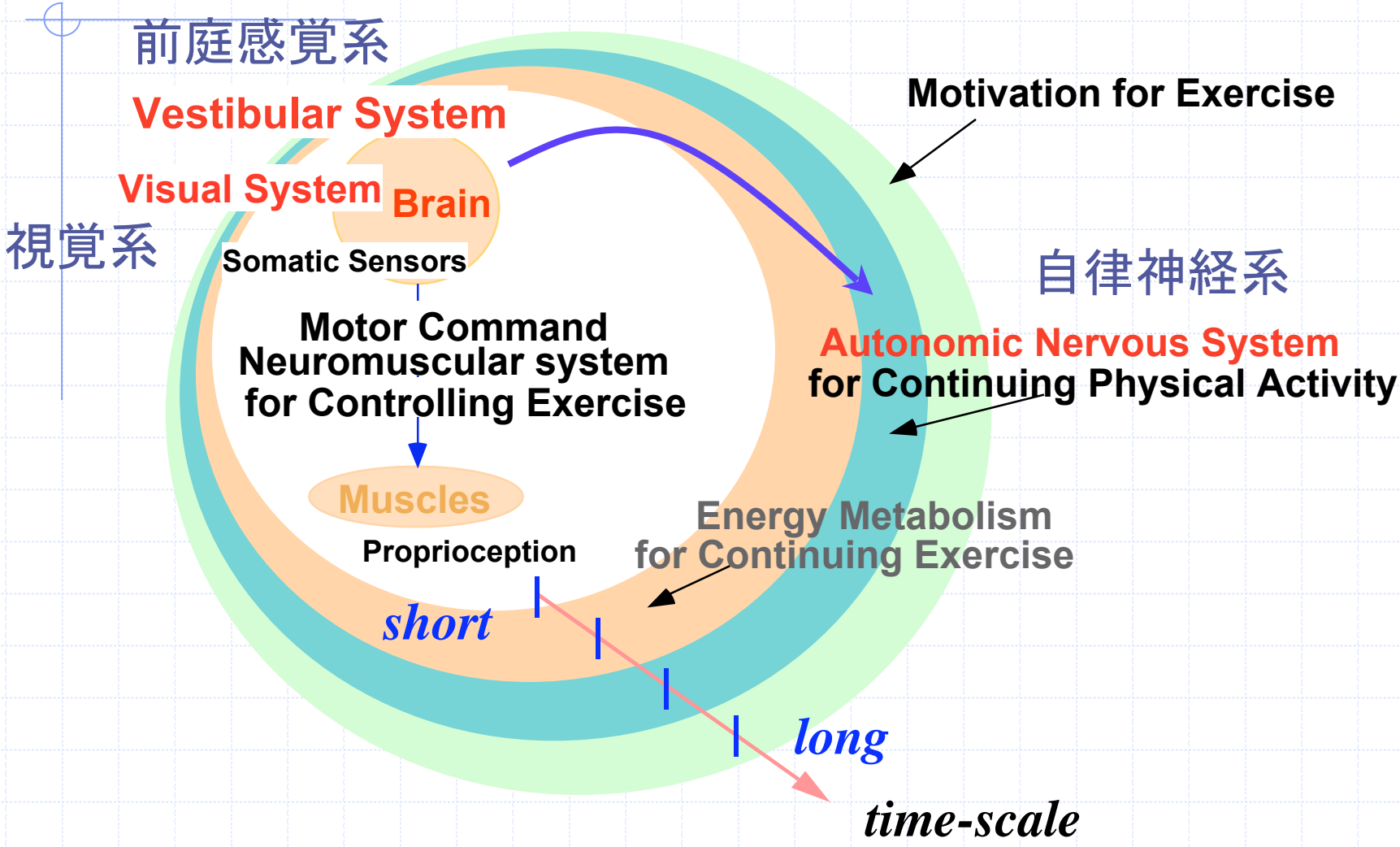
|| (*brightness, frame size, and frame rate etc.*)

*targets for evaluation*

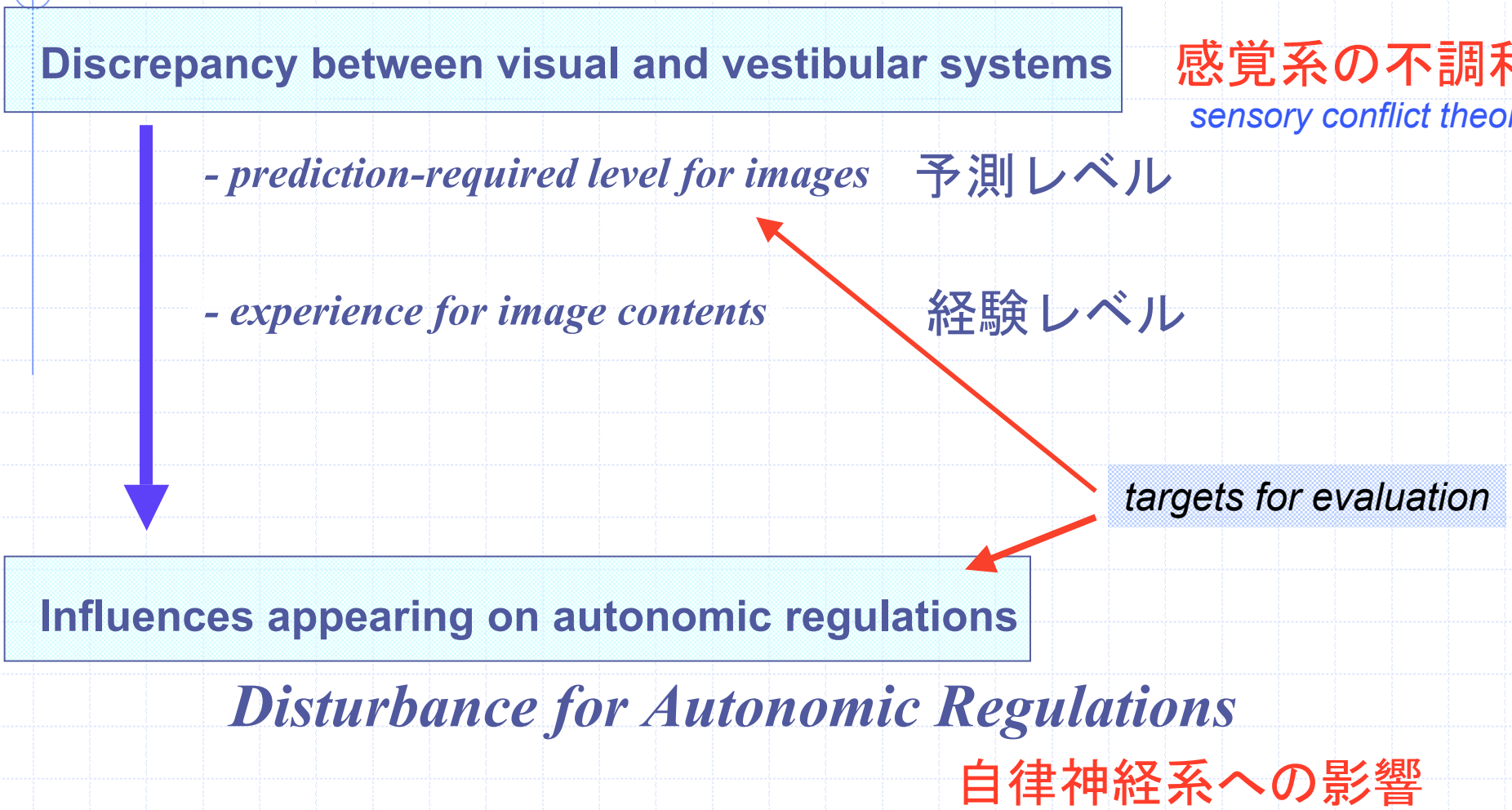
## Hierarchy of Image Components



# Several Time-Scales in Biosignals



# Rating of Personal Features
# （個人性のレイティング）



# Study Overview

*real image*

*random-dot image by CG*

viewing

*extraction*

*motion vector*

*synthesis*

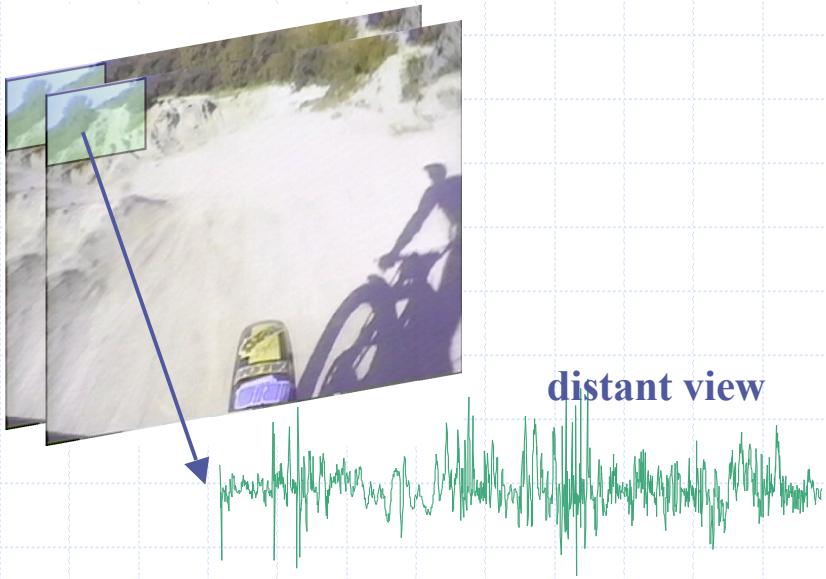
viewing

*biosignal*

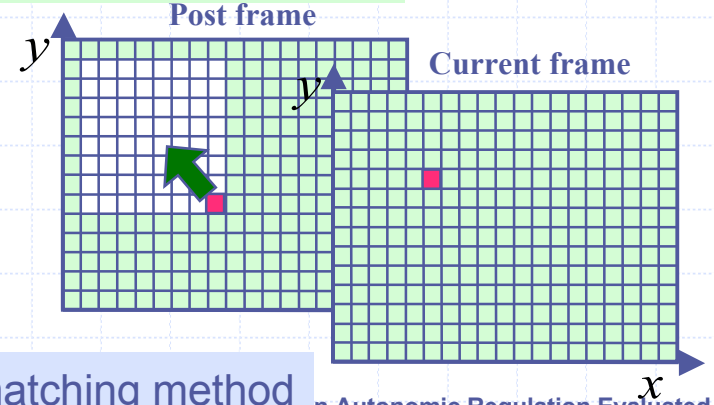
*biosignal*

# Quantization of Image by Motion Vector

## *Local Motion Vector*

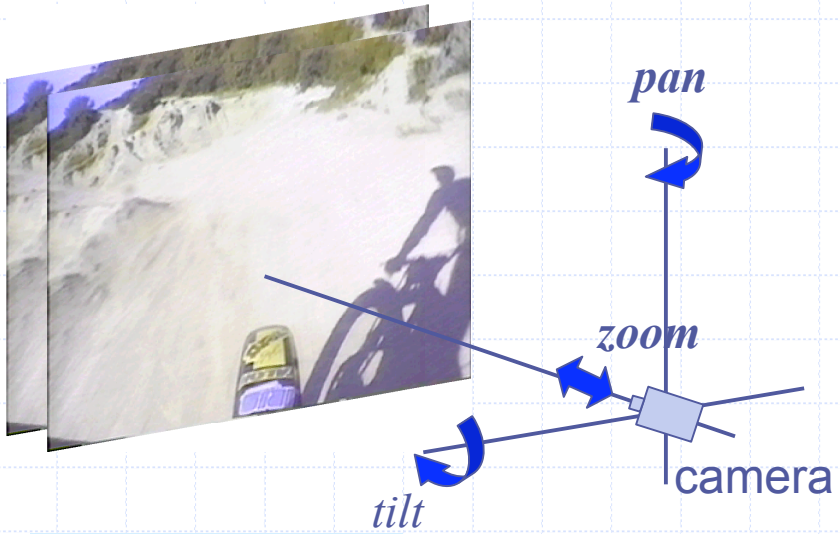



*local motion in a screen*

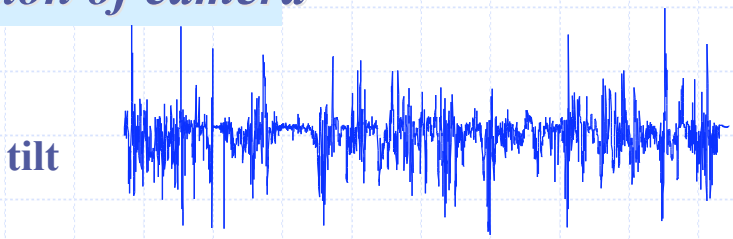



block matching method

## *Global Motion Vector*



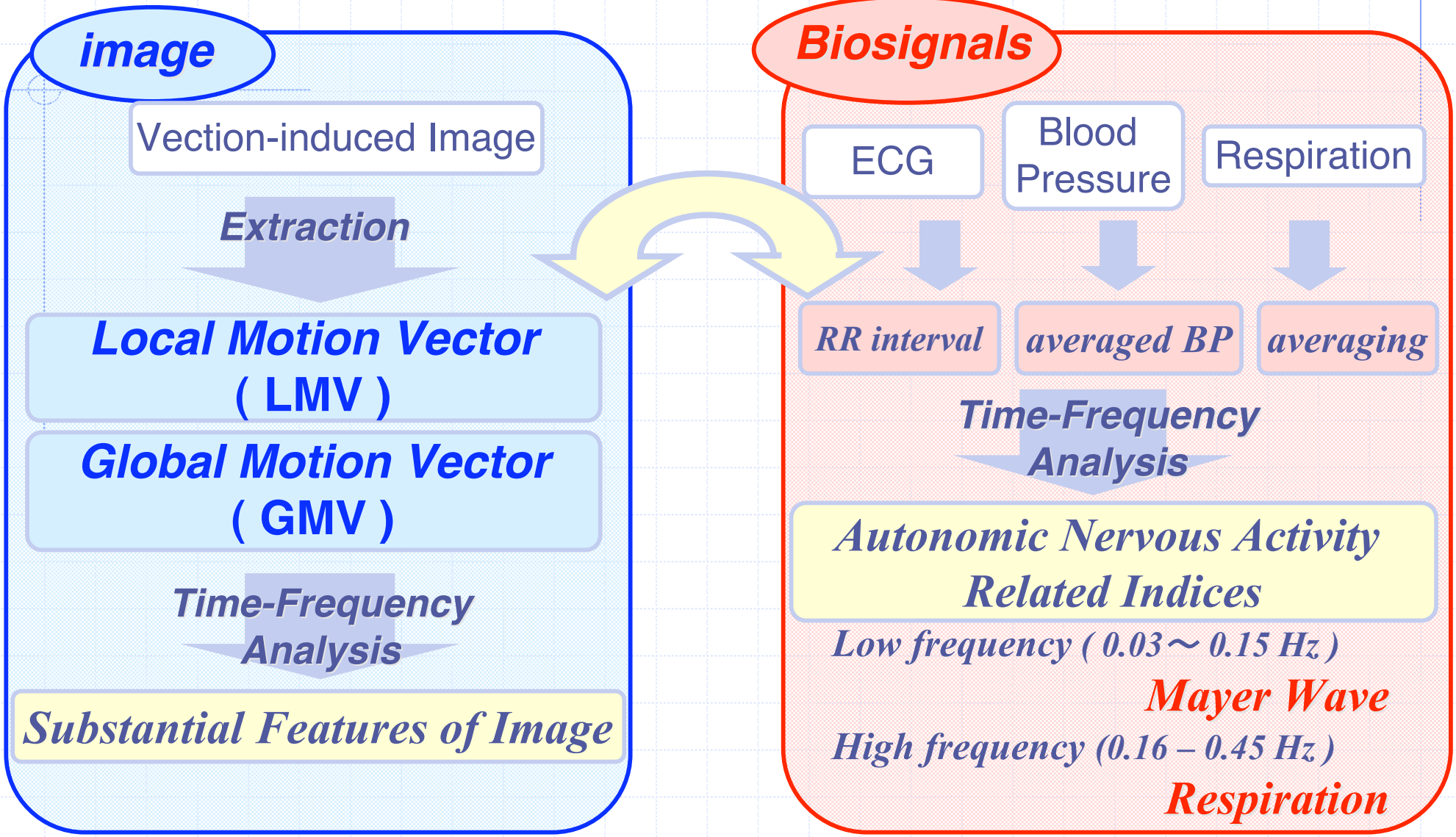

*motion of camera*




bottom up approach

秦泉寺久美ら，“スプライト生成のためのグローバルモーション算出法と符号化への適用”，電子情報通信学会和文論文誌D-II, J83-D-II, 2: 535-544, 2000.

# Signal Processing



# Experiments under Real Images

## *real images*

***Parachute***

***Bobsleigh***

***boat***

***Go cart***

***Hang glider***

***Mountain-bike***

***Car race***

***Bungee jump***

***diving***

***Bike race***

**Vehicle experiencing video**

## *subjects*

- **1st Experiment**: Five healthy elderly subjects (from 52 to 71 yrs. old) and six elderly subjects with mild hypertension or diabetes mellitus (5 males and 1 female from 50 to 71 yrs. old) .
- **2nd Experiment**: ten healthy young subjects (8 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

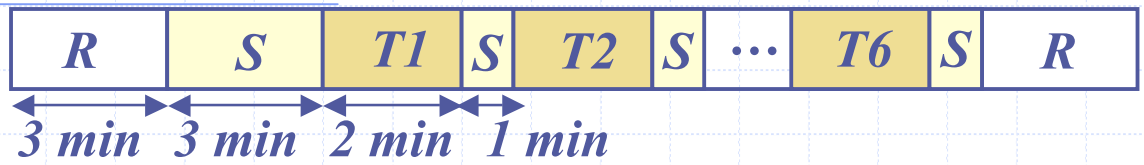
***Blood flow***: Laser Doppler at thumb sphere of left hand

***Perspiration***: Capsule type sensor at thumb sphere of left hand

at Niigata University （Nov. 13, 14, 1999, Jan. 19, 21, Mar. 17, 2000）

# Searching Candidates from Components of Motion Vectors（動きベクトルの要素を探る）

## Experimental Protocol




*R* : rest　　*S* : still picture　*T* : test under conditioned image

## Subjects

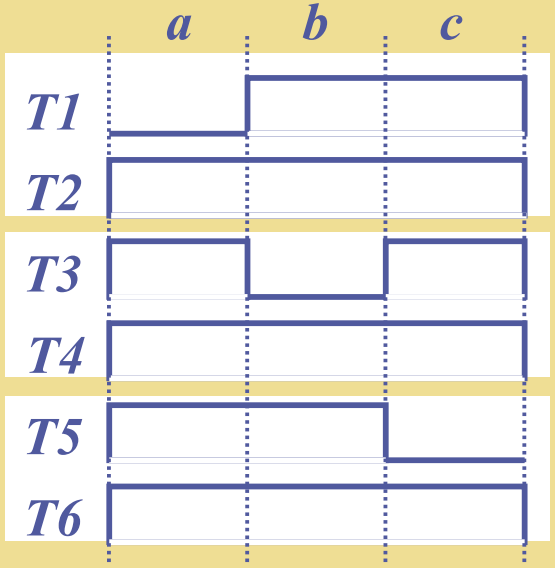
Ten healthy young subjects (8 males and 2 female from 21 to 24 yrs. old)

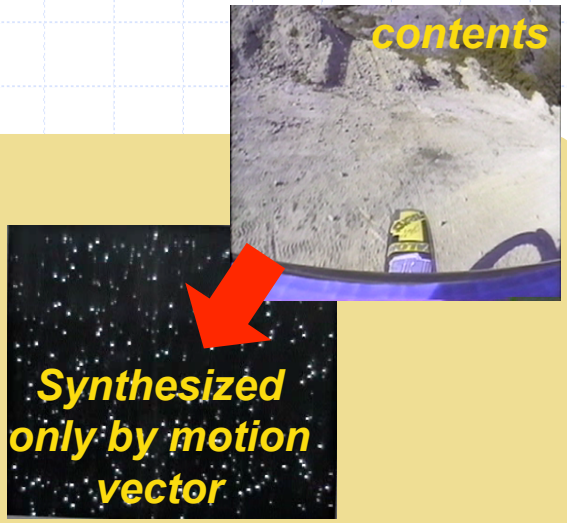
***random-dot pattern synthesized by CG***

based on motion vectors from real mountain bike image

### Comparison between

1. *GMV and LMV*
2. *among GMV parameters*
3. *among LMV parameters*
4. *among frequencies*
5. *among frequencies for switching*



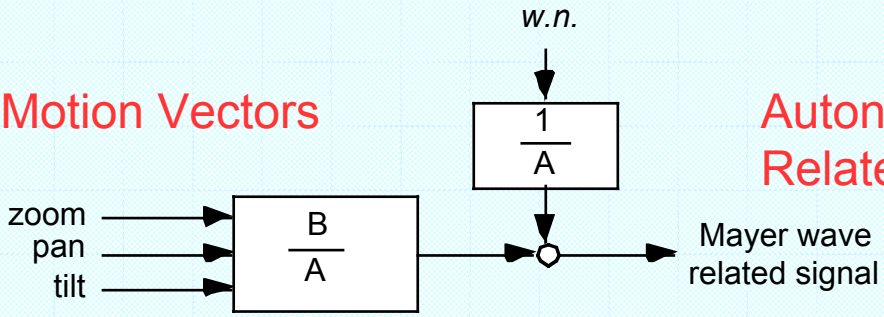

*a : zoom*
*b : pan*
*c : tilt*

at Niigata University on Dec. 1-22, 2002.

# ARX Model with Time Delay

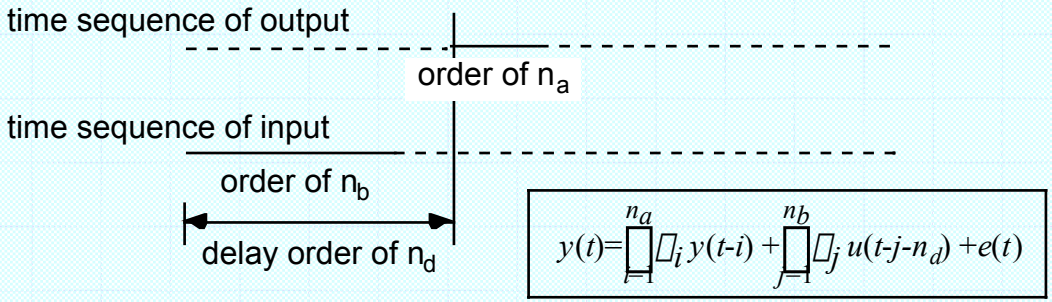
*input-output*

Components of Motion Vectors

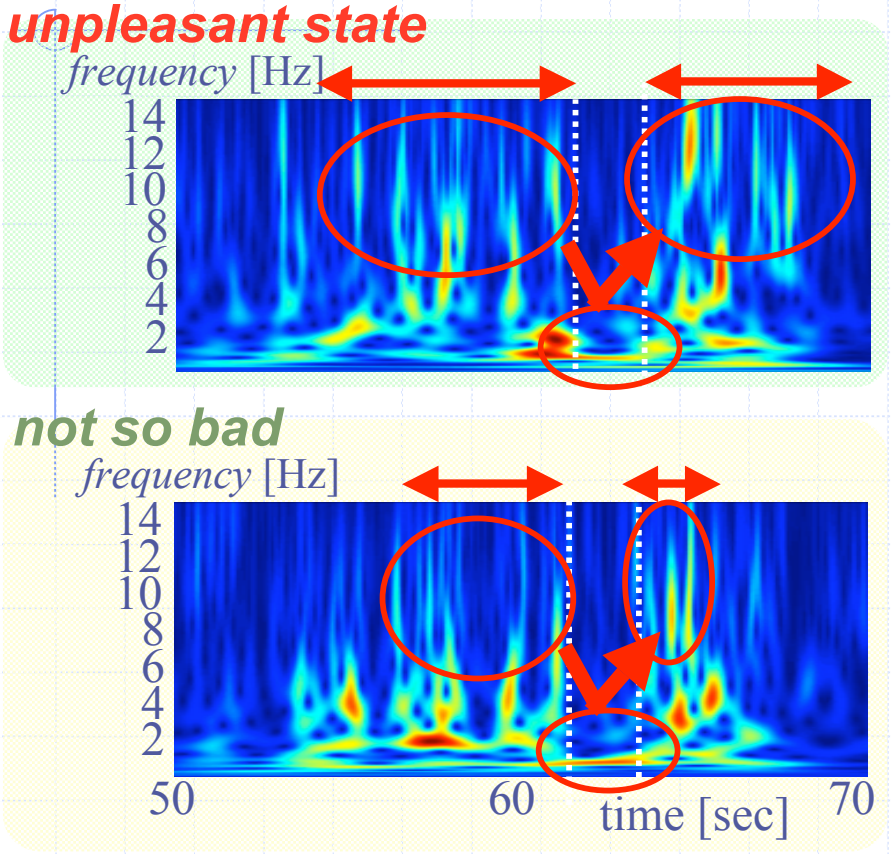


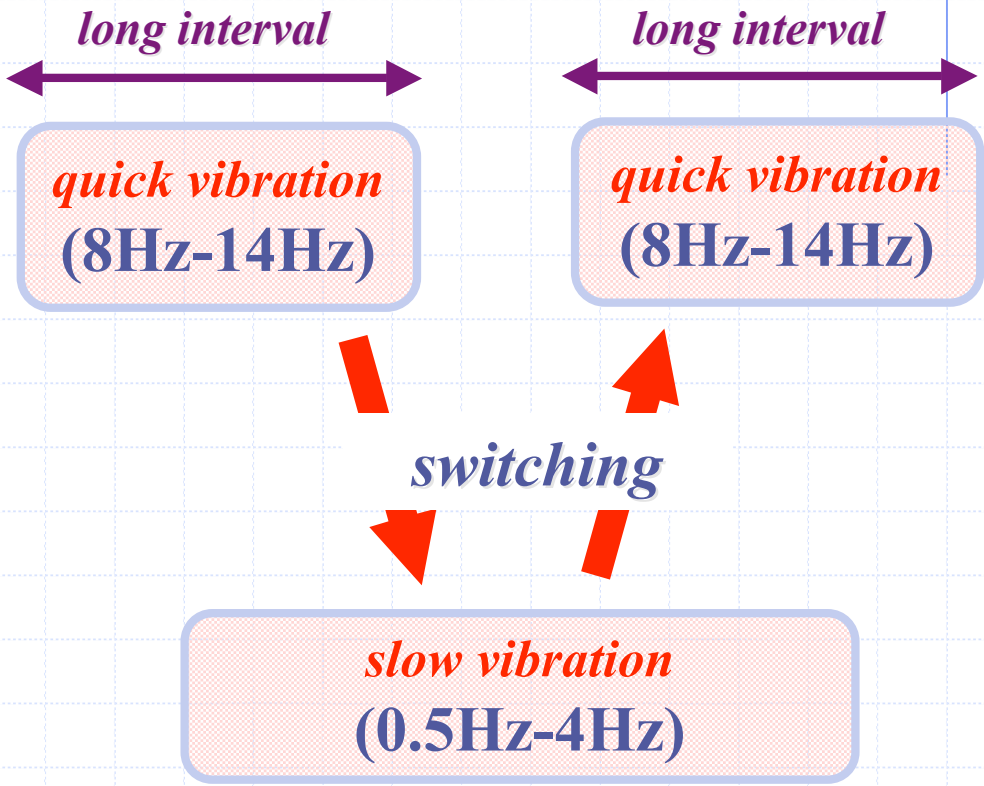

Autonomic Nervous Activity Related Index

*time sequence*



# Time-varying Behavior of Motion Vectors in Unpleasant State（不快な場面での動きベクトル）




- *quick vibration of motion vectors possibly affect on autonomic regulations*
- *switching of frequency ranges and their exposure time intervals*

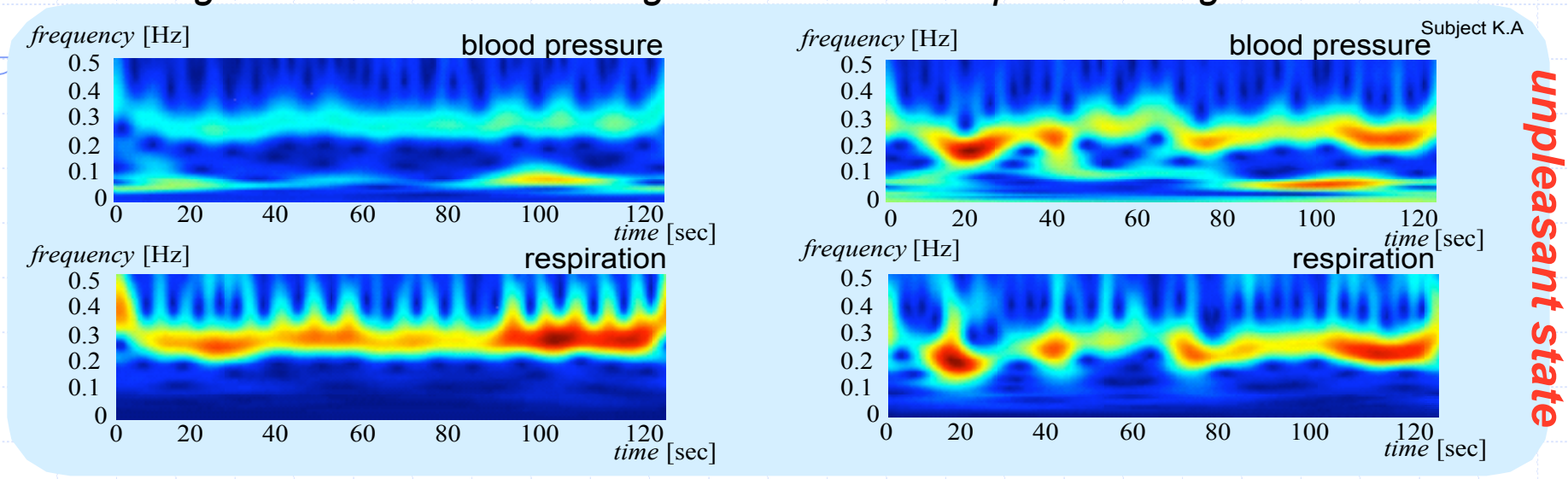
# TFRs of Biosignals under Real and CG images

*Real image of mountain-bike riding*

*Random-dot pattern image based on real image*

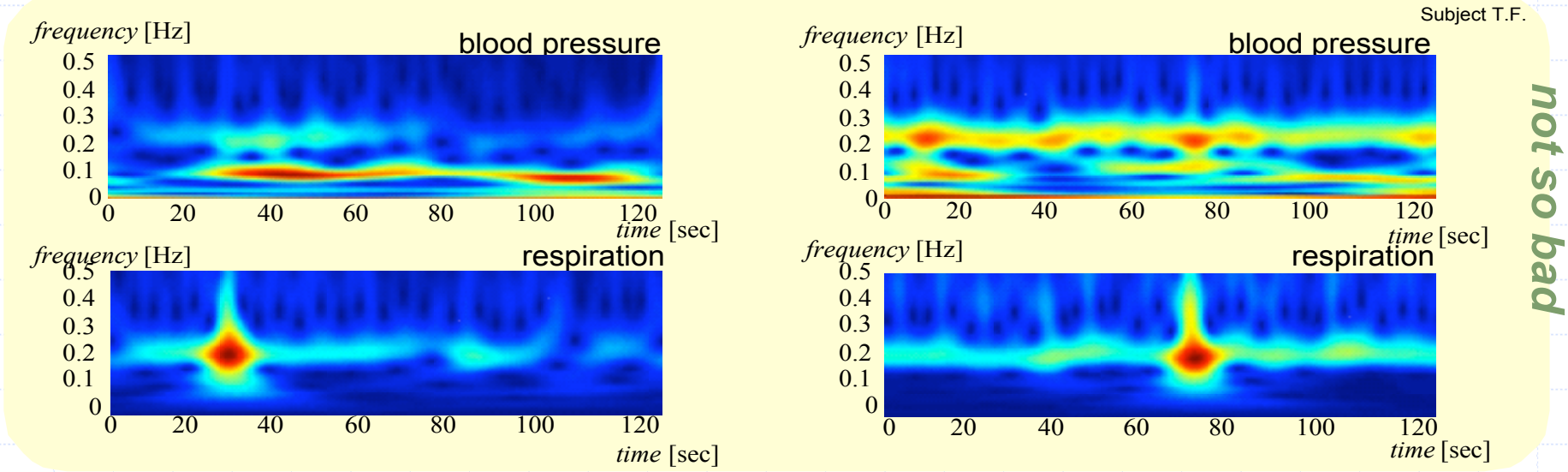
not so bad

unpleasant state




unpleasant state

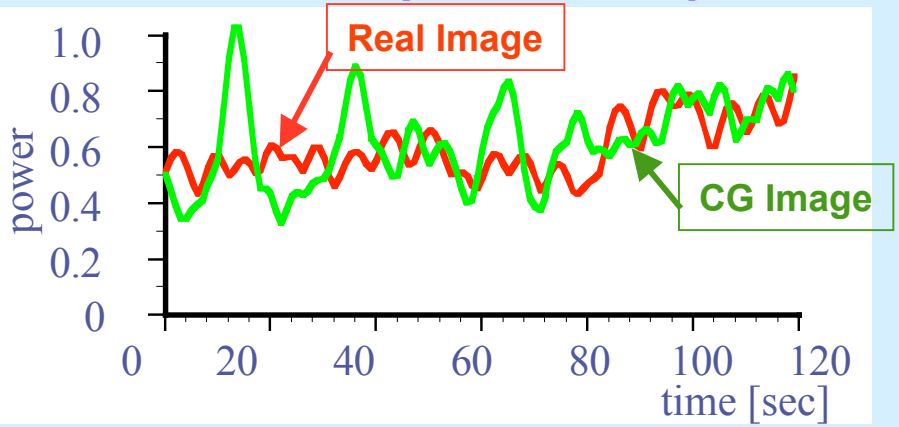
not so bad



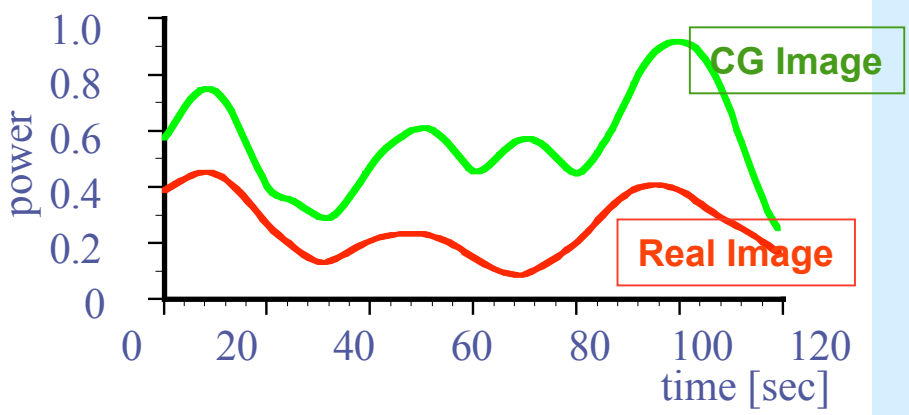
# HF and LF Components of Biosignals

*low frequency : 0.03 – 0.15 Hz*
*high frequency : 0.16 – 0.45 Hz*

## HF power of respiration



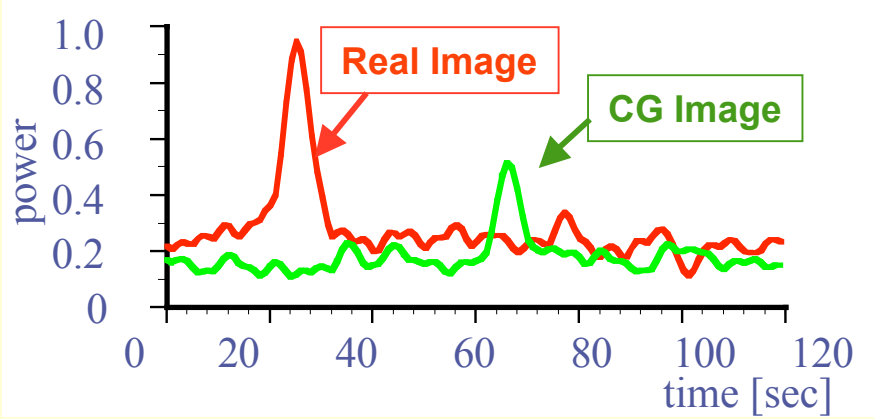

## LF power of blood pressure



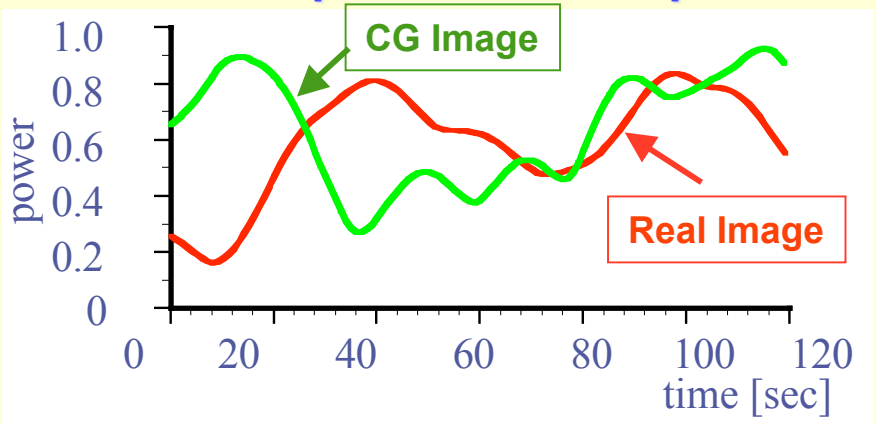

***unpleasant state appeared for CG image***

Subject KA

## HF power of respiration



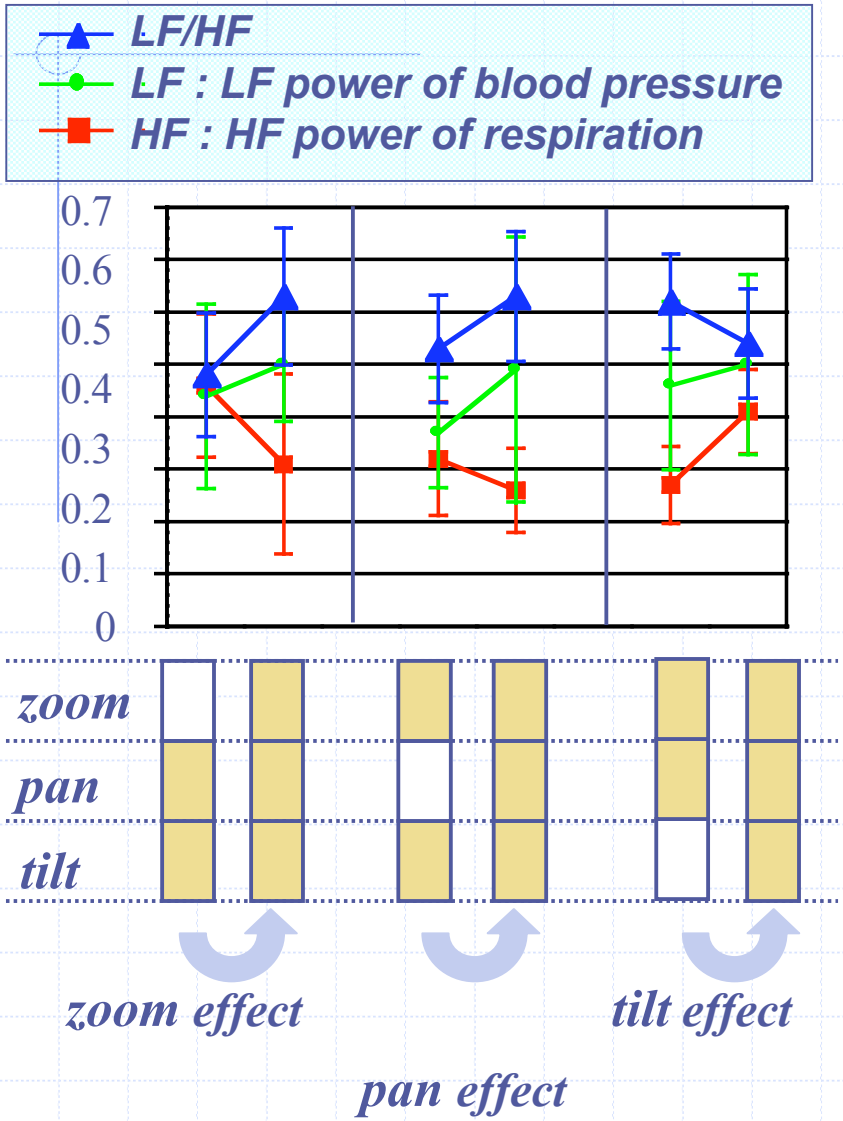

## LF power of blood pressure




***unpleasant state appeared for real image***

Subject TF

# Changes in Autonomic Indices affected by Components of Motion Vectors




*low frequency : 0.03 – 0.15 Hz*
*high frequency : 0.16 – 0.45 Hz*

ズームとパンは交感神経に影響

***Adding zoom- and pan-components caused decrease of HF, increase of LF and LF/HF.***

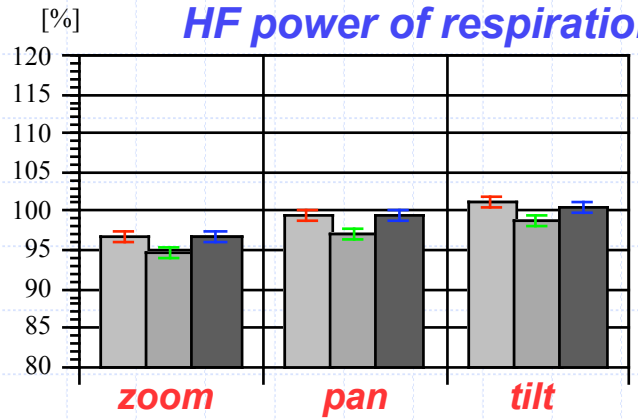
***→ degeneration of parasympathetic nerve activity and enlargement of sympathetic nerve activity***

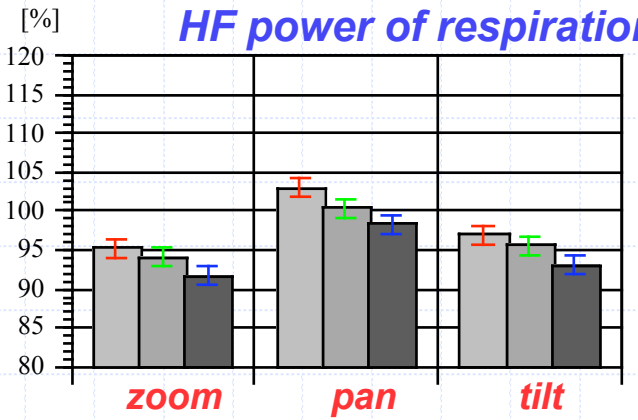
チルトは副交感神経に影響

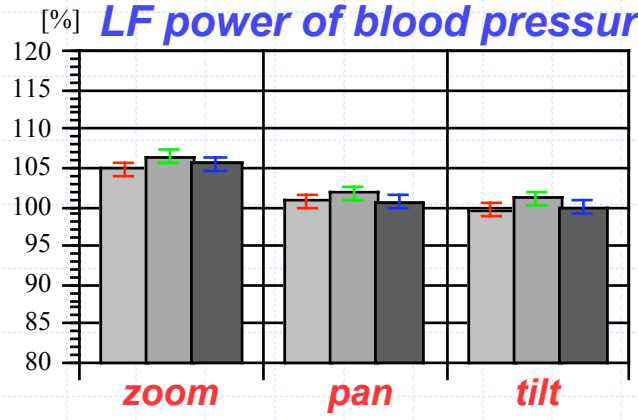
***Adding tilt-component caused increase of HF and LF, and decrease of LF/HF.***

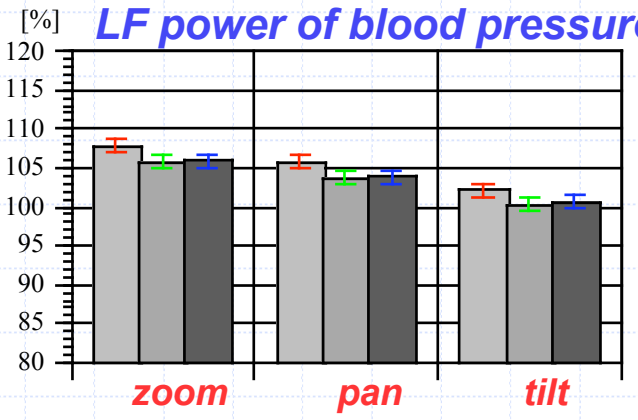
***→ degeneration of sympathetic nerve activity and enlargement of parasympathetic nerve activity***

# Influences of Motion Vector Components



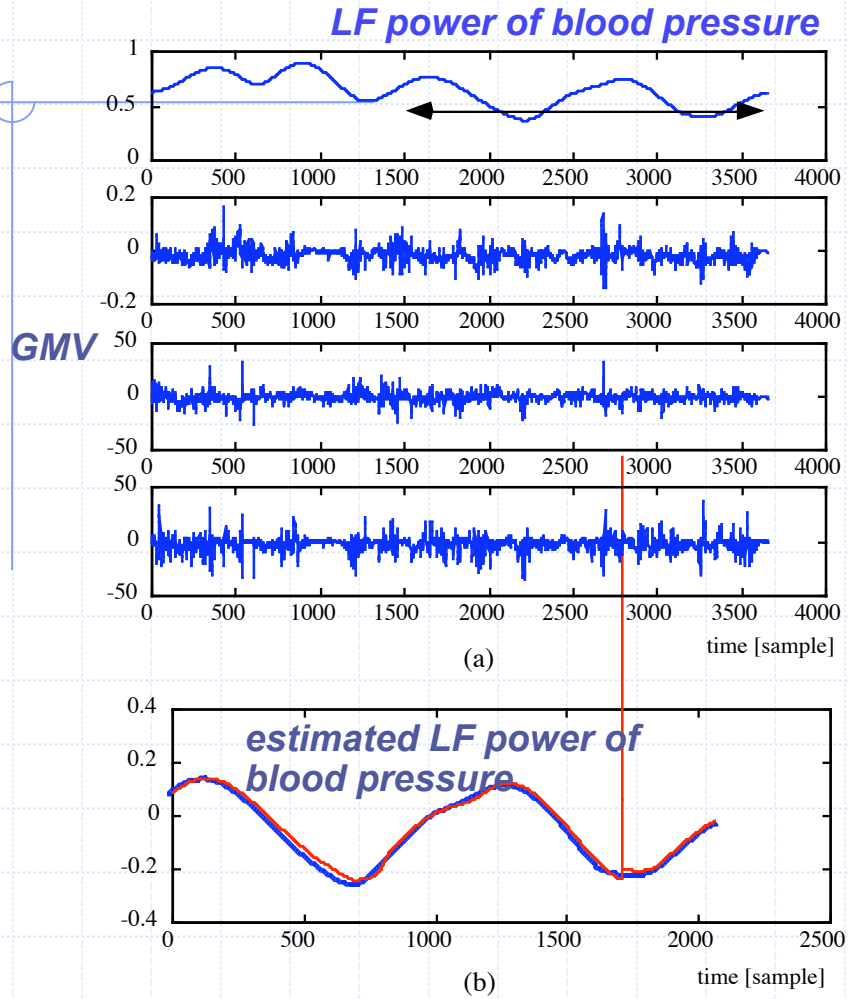



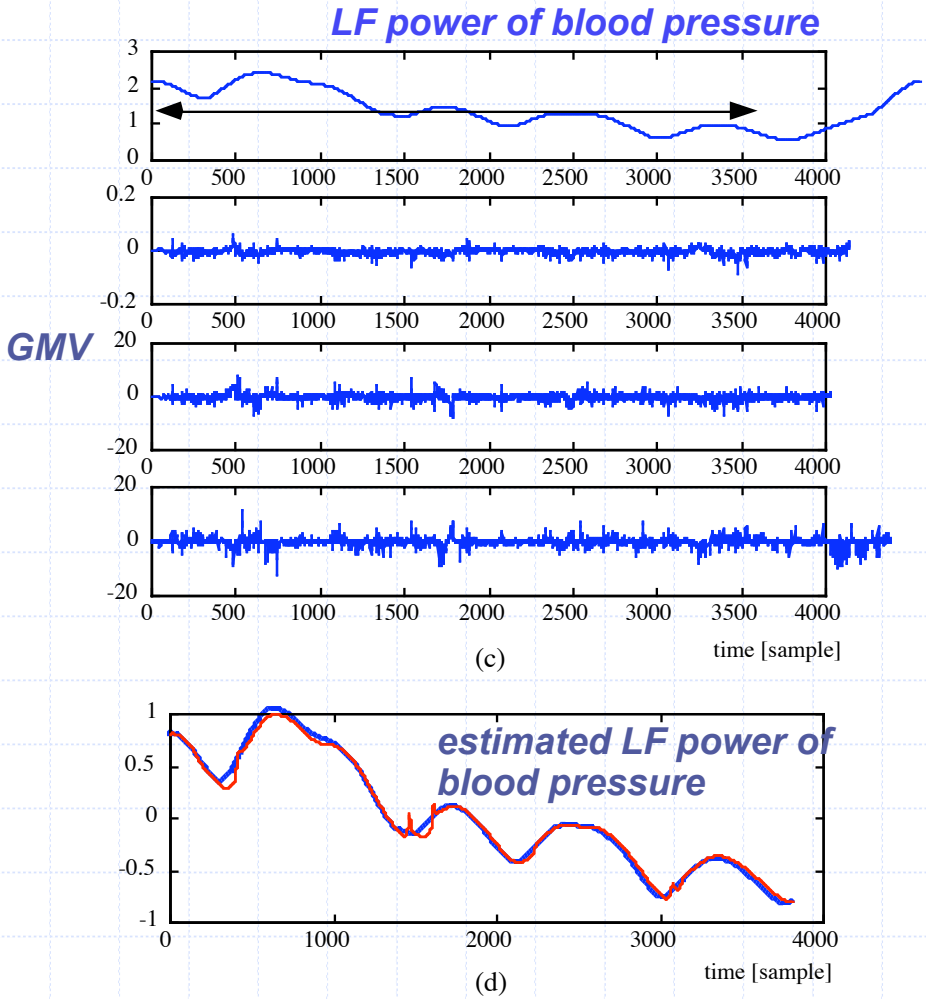




Variation Ratio = (ANA related index with full GMV components) / (ANA related index without a specific GMV component)

# Results for ARX Model



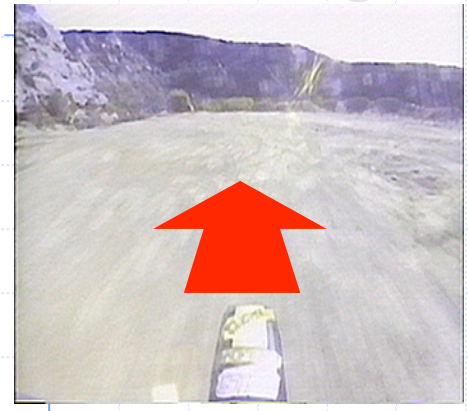

mountain bike riding image

bike race image

The length of interval for estimation was 50 sec. The appropriate $n_d$ was 90 under the condition that $n_a$ and $n_b$, were 2.

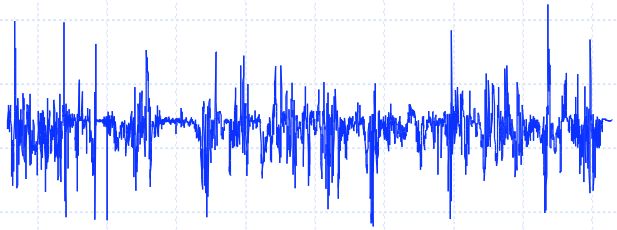
# Discussion（実写とCGの違い）
## – Differences between Real and CG Images –

***Real Image***



*able to predict*

***same motion vector***



視覚系と前庭系

***CG Image***

*unable to predict*

## *Effect of Image Contents*

- *psychological element*
- *prediction based on experience*
- *prediction based on spatial*

acknowledgment *of real environment*

実写映像のコンテンツが予測を
助けている

***Visual & Vestibular info.***

不調和

*miss match*

*prediction*
予測

×

*accumulation*
蓄積

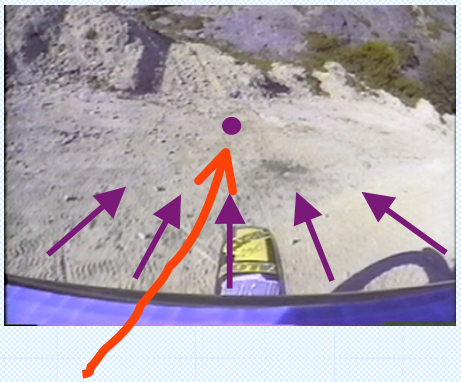
## *Disturbance of Autonomic Regulations*
自律神経系への外乱

# Discussion（実写とCGの違い）

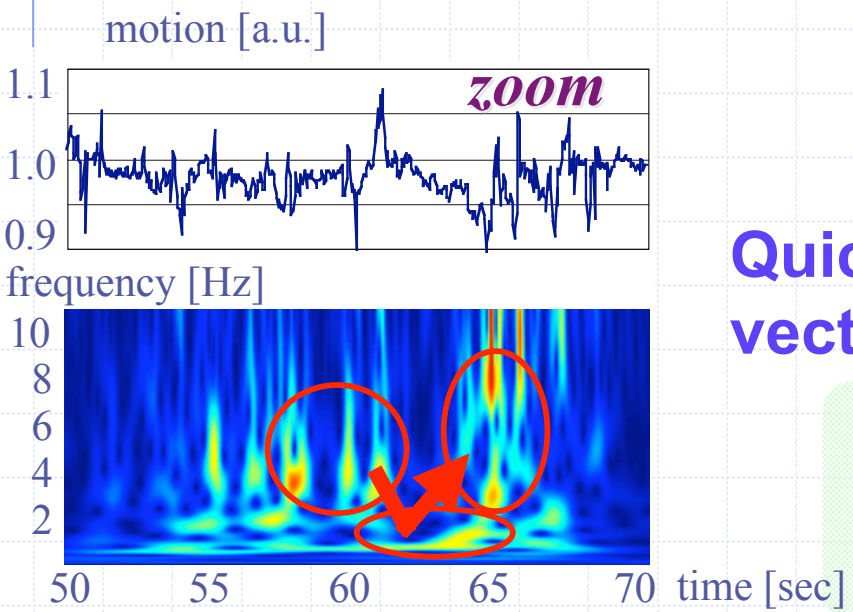
## – Prediction of Traveling direction by and Motion Vector –

*Zoom component affected on autonomic regulations, referring to the experimental results.*
*ズームが自律神経系に影響を与えていた*

*ズームを予測に使用しているのではないか.*



*zoom component might be used for prediction of traveling direction*




**Quick vibration appeared in motion vector could disturb prediction**

*動きベクトルの周波数の急激な変化→*
***予測に反する動き***

# 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 switching behavior in the vibration frequency and, zoom and pan components of global motion vectors possibly caused cybersickness.

- The multivariable ARX model as the system function approach would be effective for screening the level of cybersickness for individuals.

- 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).