Modelling Breath Flow Time Series

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Breath Flow and Heart Rate

RSA
(Respiratory Sinus Arrhythmia)

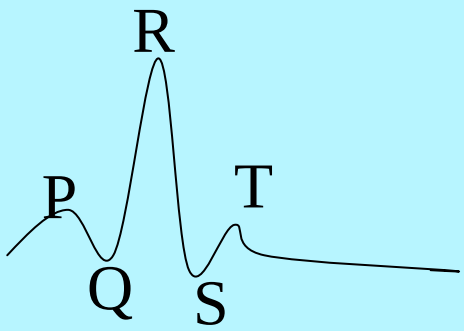
Breathing → Heart Rate

Blood pressure → MWSA
(Mayer Wave Sinus Arrhythmia)

↑ Task

Data

- Peak time of R-wave
  - Point Process
  - 16-20 peaks /minute



- Breath flow Speed
  - Regularly observed Time Series /0.5sec
  - Litter/sec $\pm$
  - 8 -9 litter/minute

- Task(mental arithmetic) $\times$ Health Condition
  - Before Task, During Task, After Task
  - Good Health Condition, Bad Health Condition

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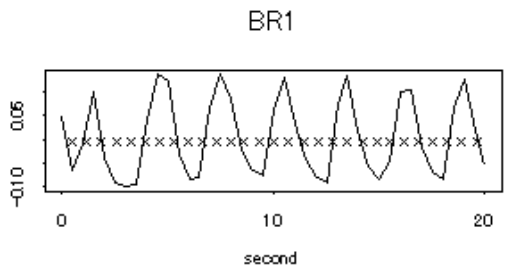
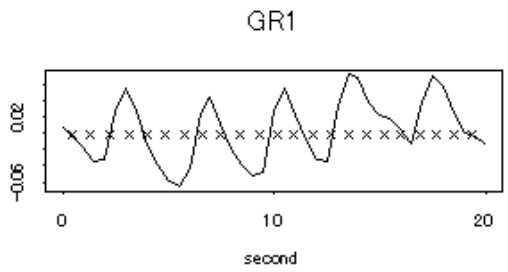
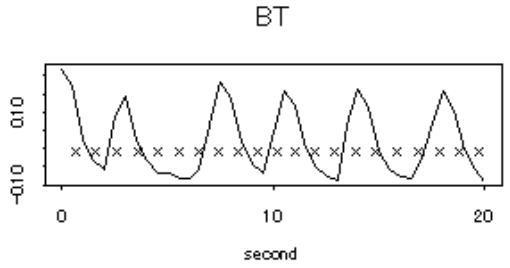
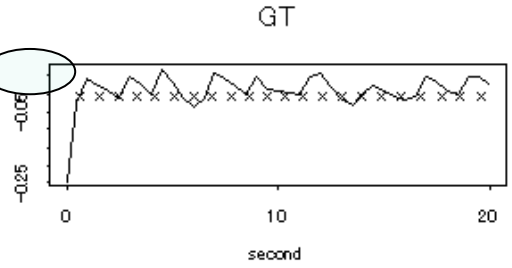
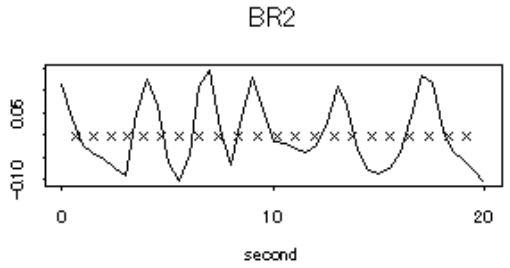
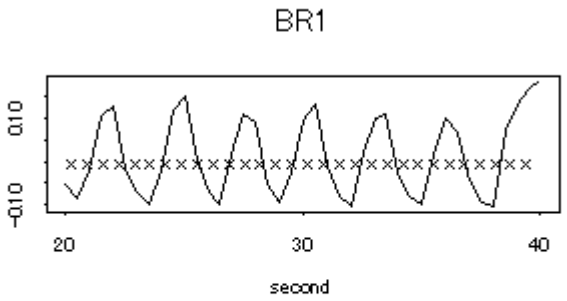
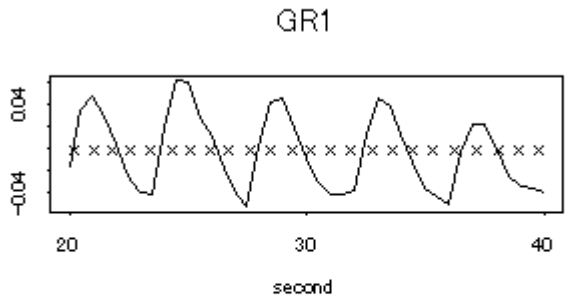
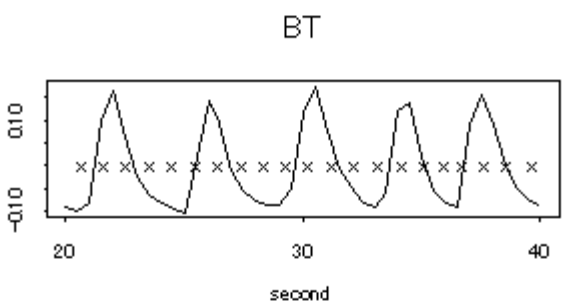
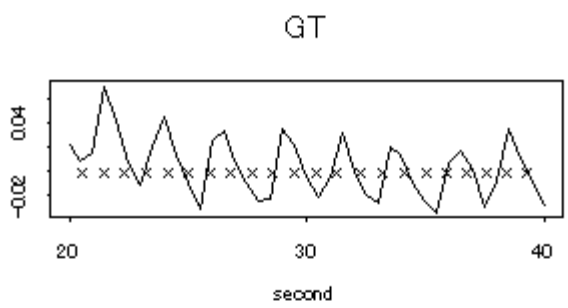
	Bad Health Condition	Good Health Condition
Before Task		
During Task		
After Task		

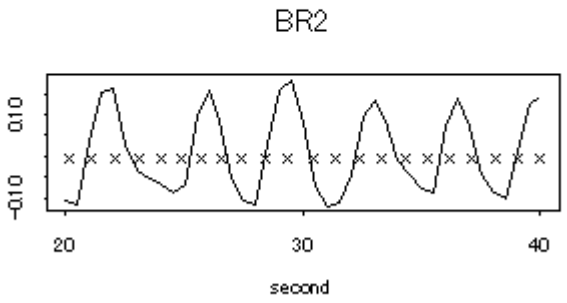
Next Block


BR1
0.10
-0.10
20
30
40
second


GR1
0.04
-0.04
20
30
40
second

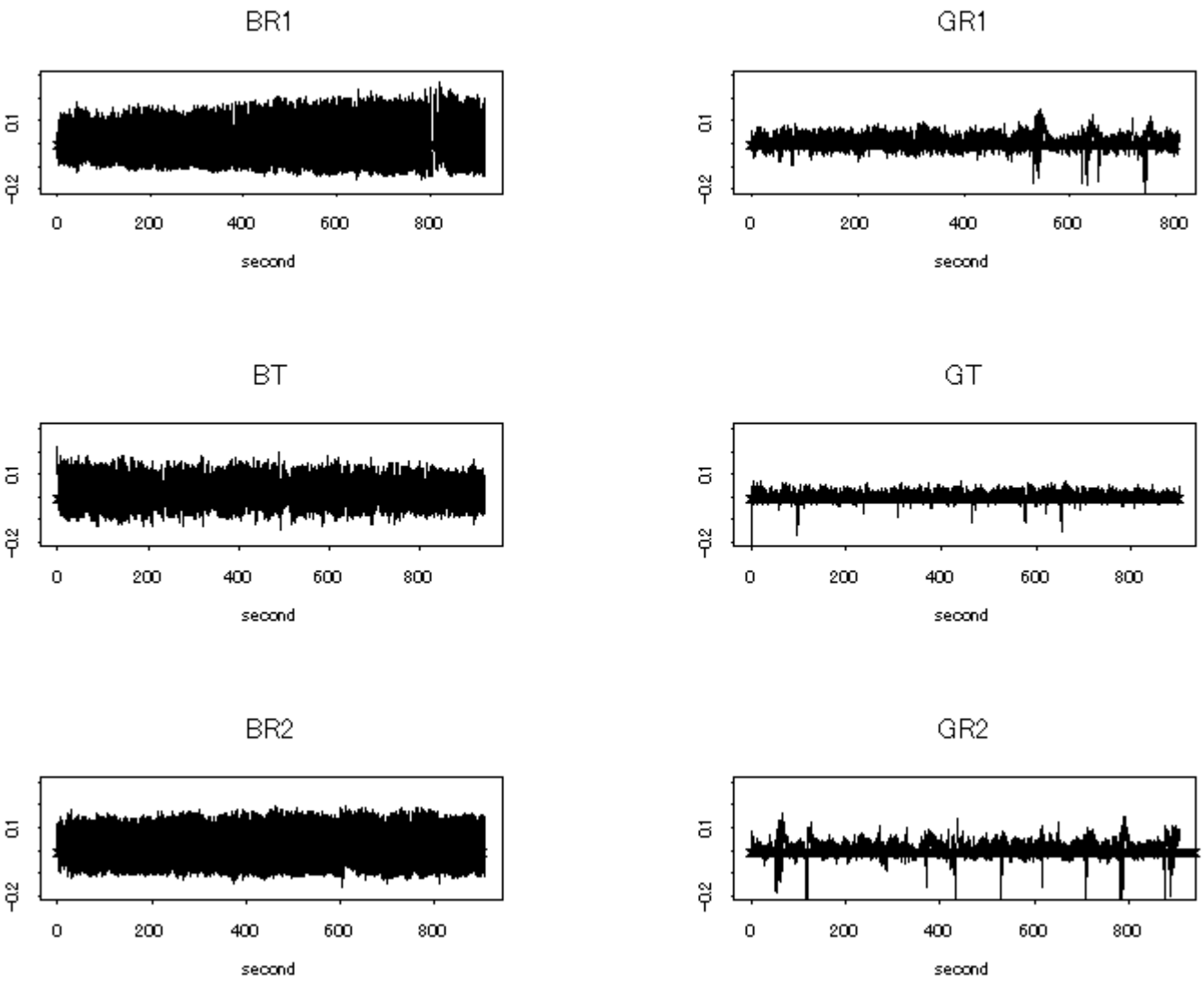

BT
0.10
-0.10
20
30
40
second


GT
0.04
-0.02
20
30
40
second

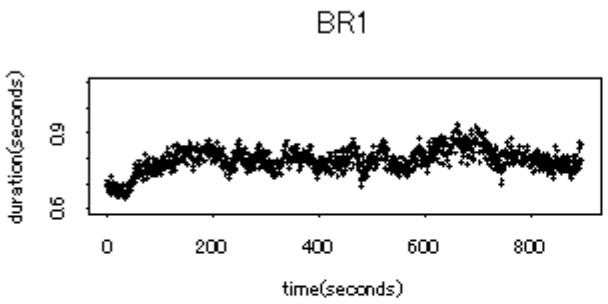

BR2
0.10
-0.10
20
30
40
second

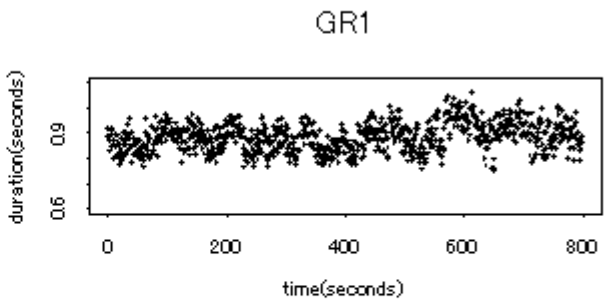

GR2
0.0
-0.05
20
30
40
second

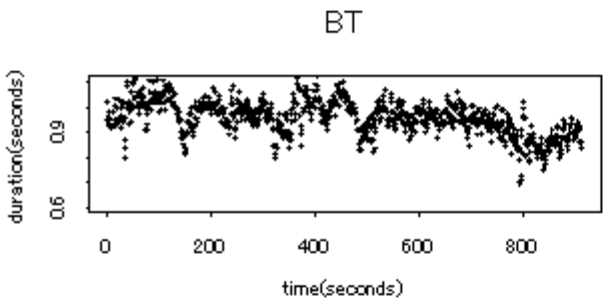
Whole Breath Flow Time Series

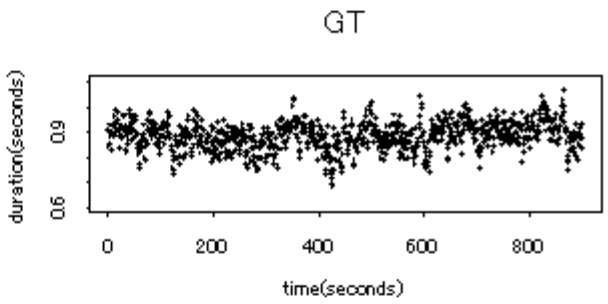


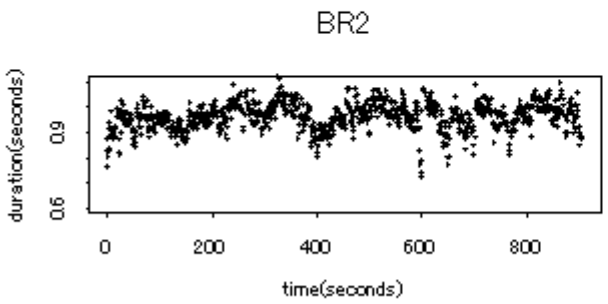
Whole durations of R-R peaks

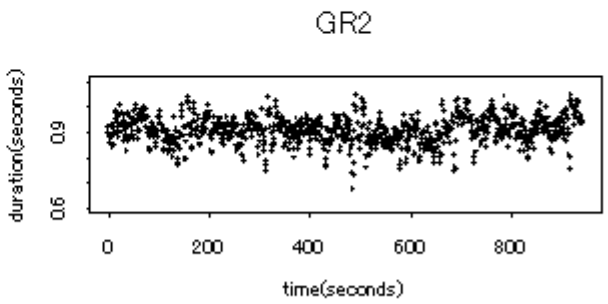




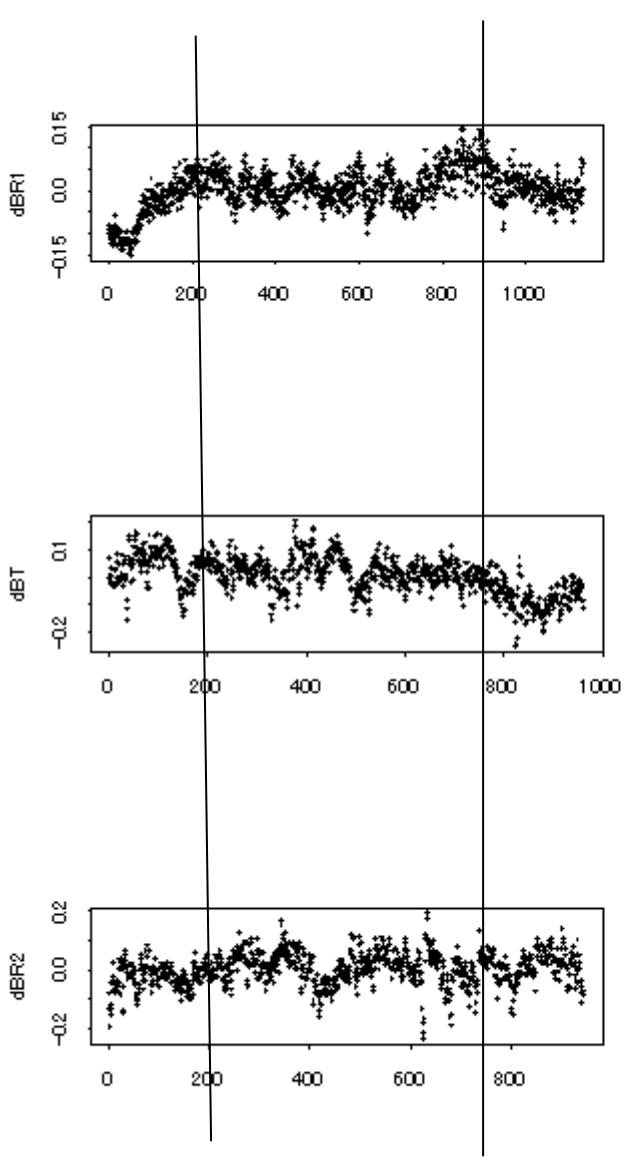


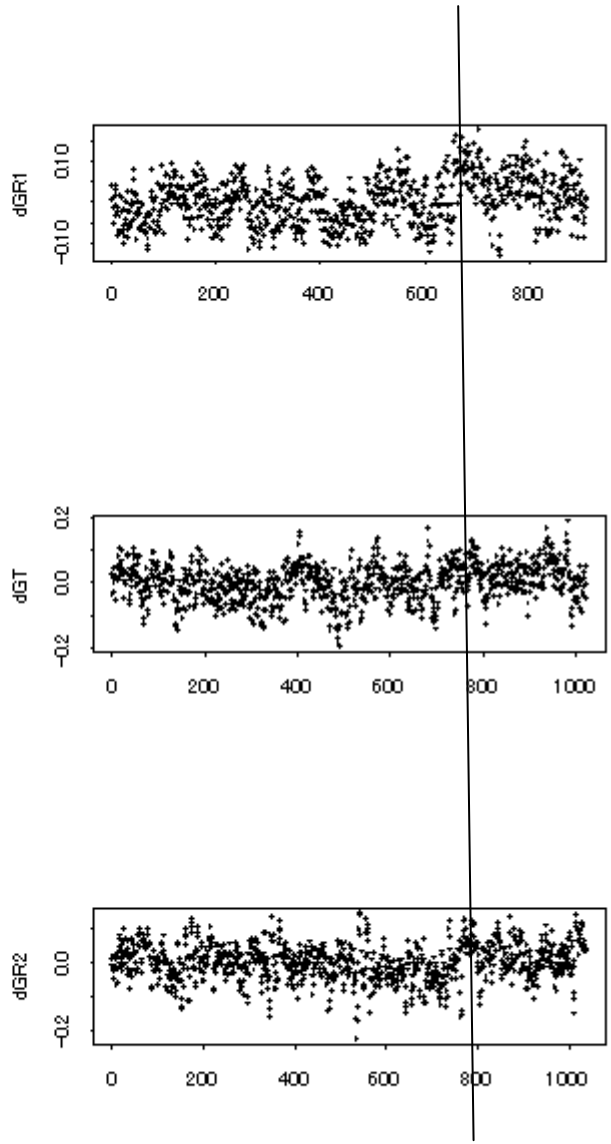






Homogeneous Part





Breath Flow Time Series

- Almost Cyclic
  - Randomness: Value, Cycle
- The aim of model building
  - Effect of Task and Health Condition
  - Input to Breath-HeartBeat System

$$X(t) = R\cos(\theta t + B(t)) \ ?$$

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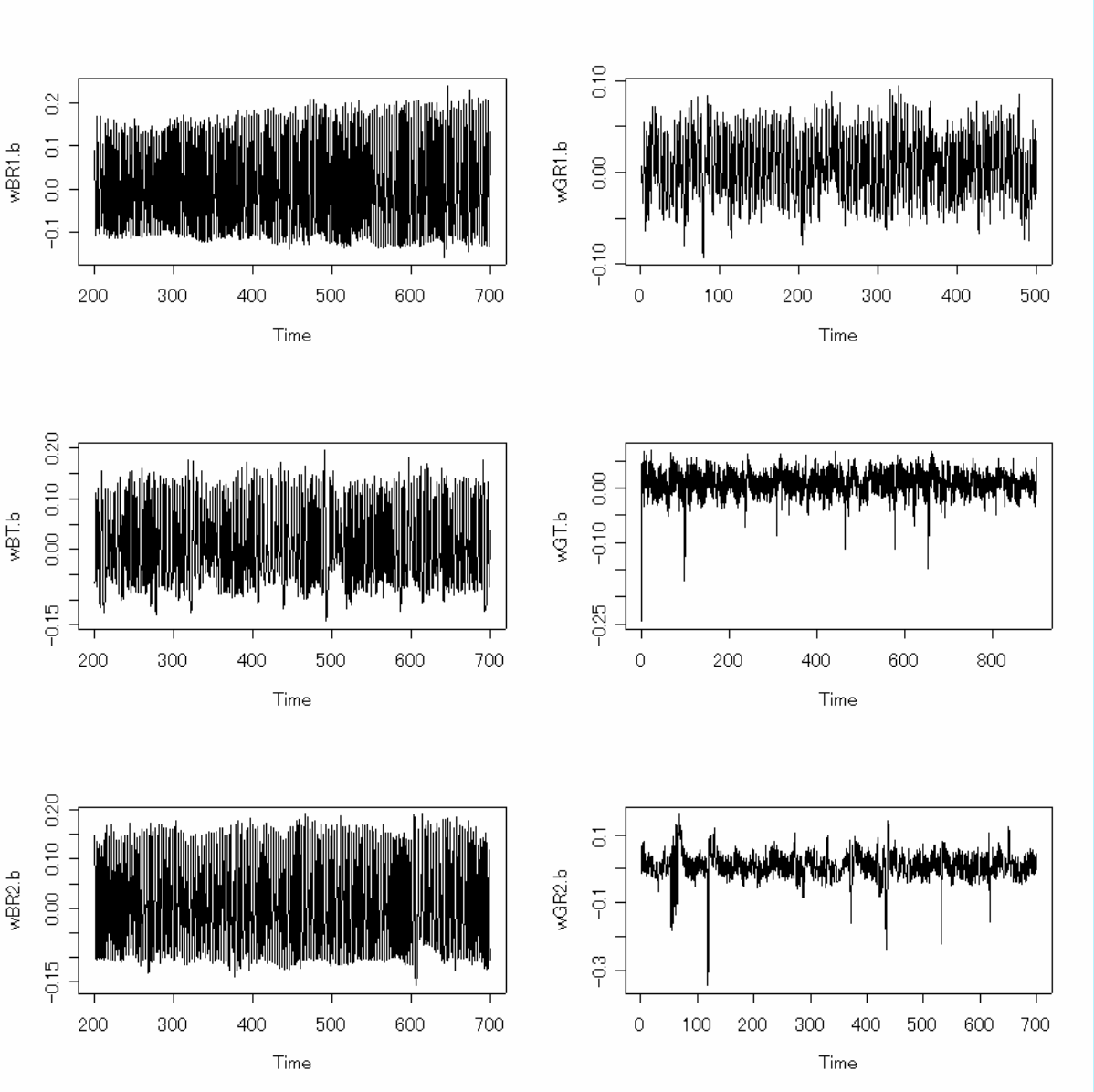
Bad Health Condition Good Health Condition

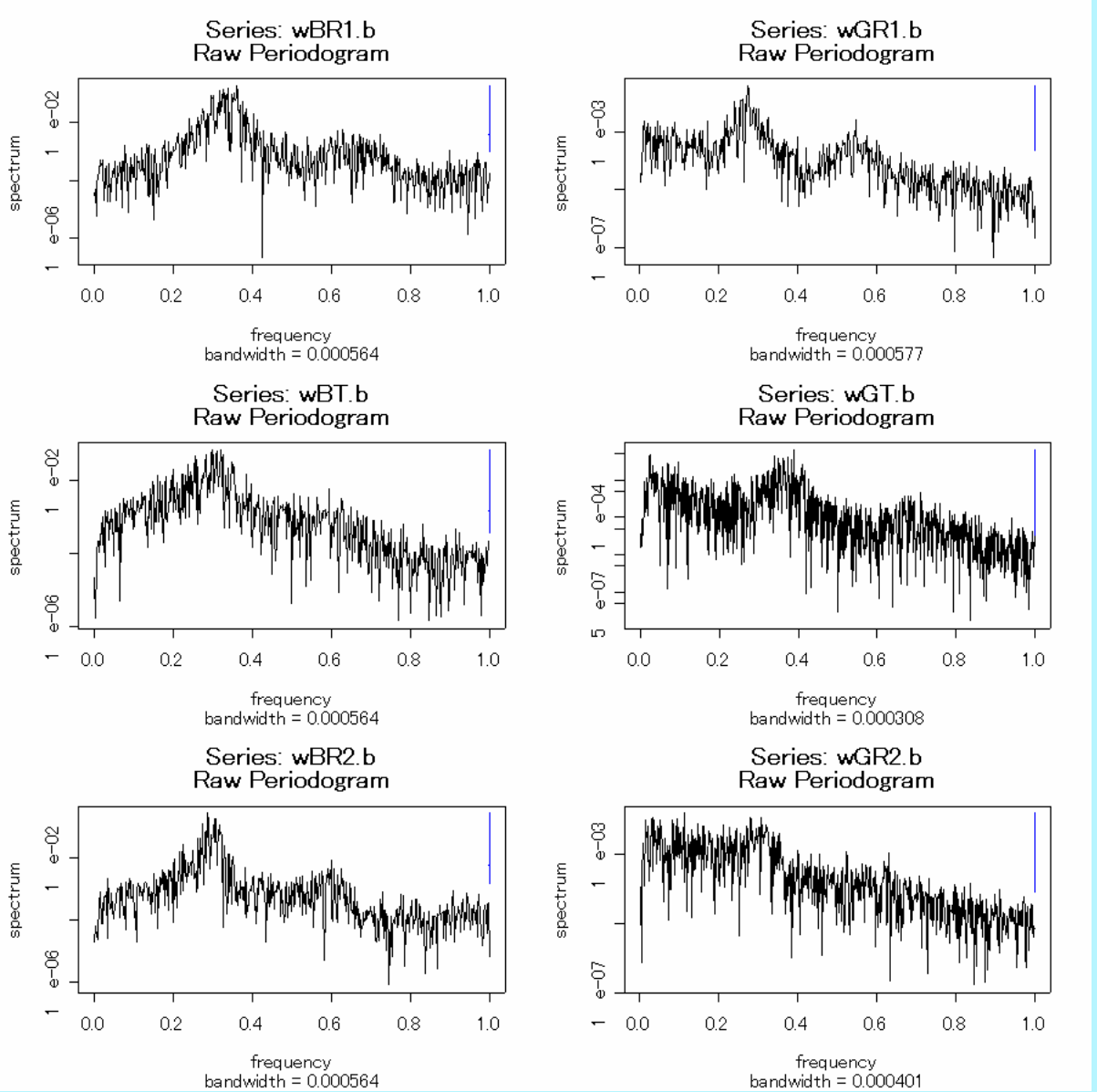
Before Task

During Task

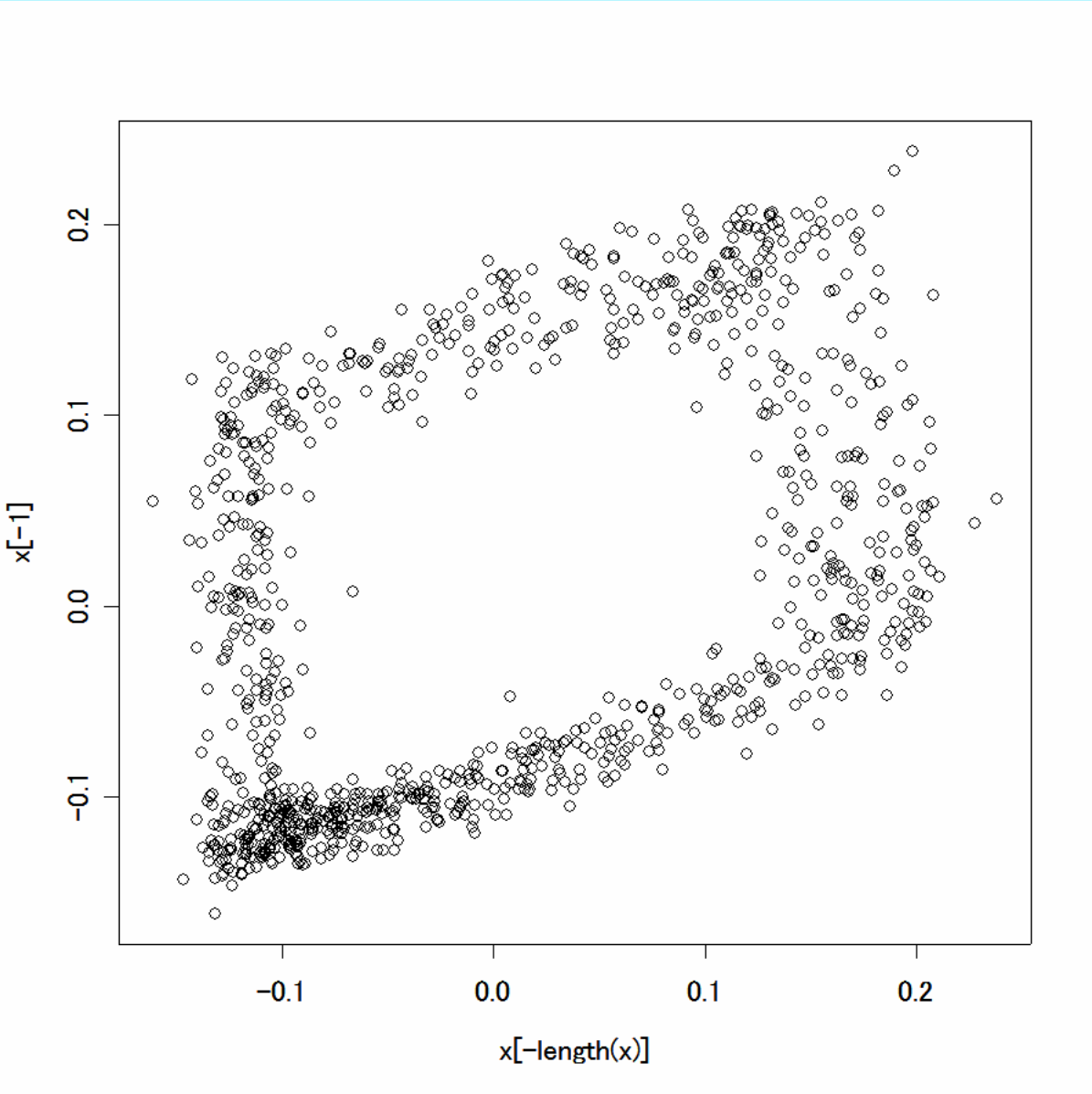
After Task



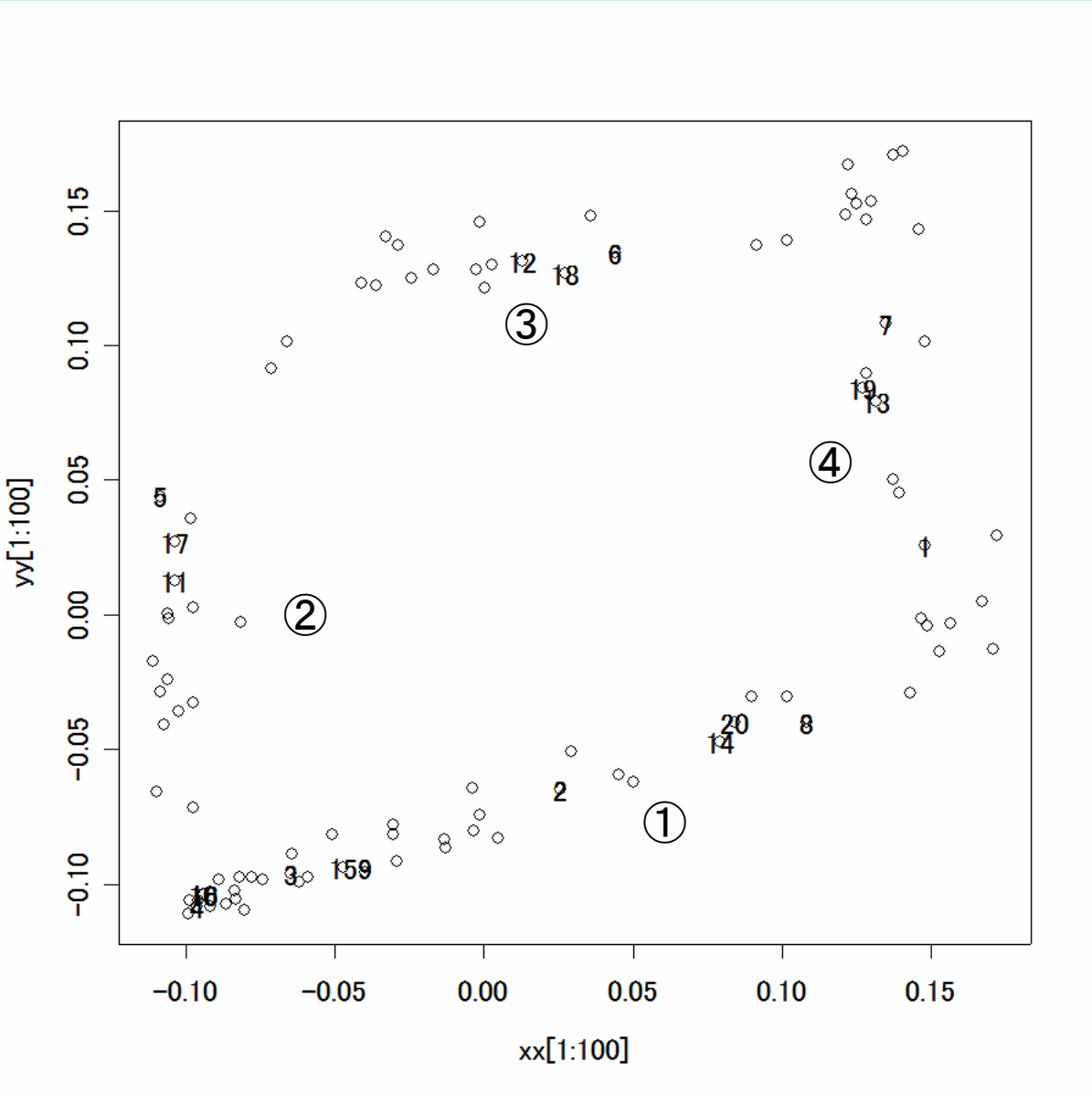
Periodgrams

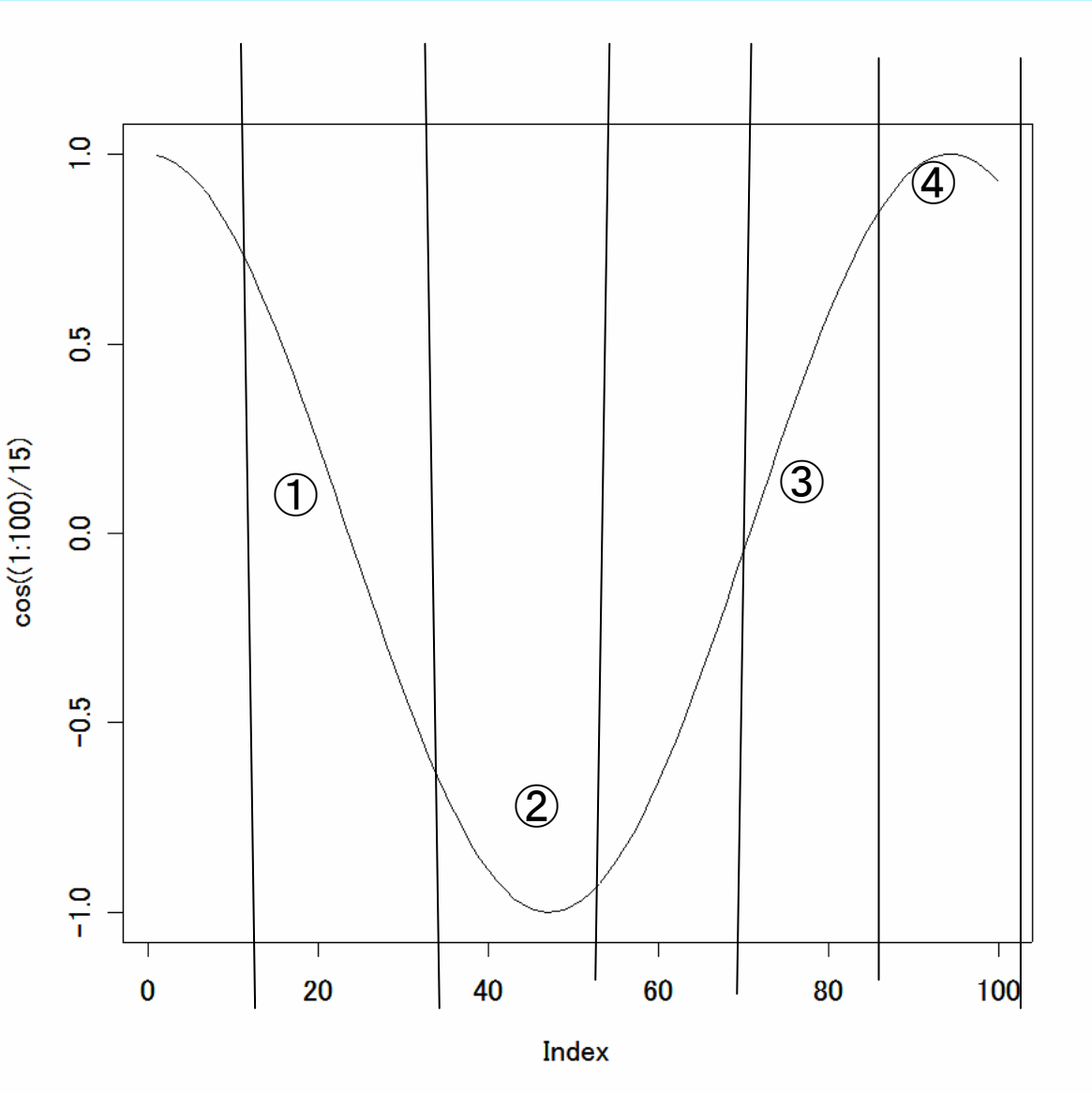


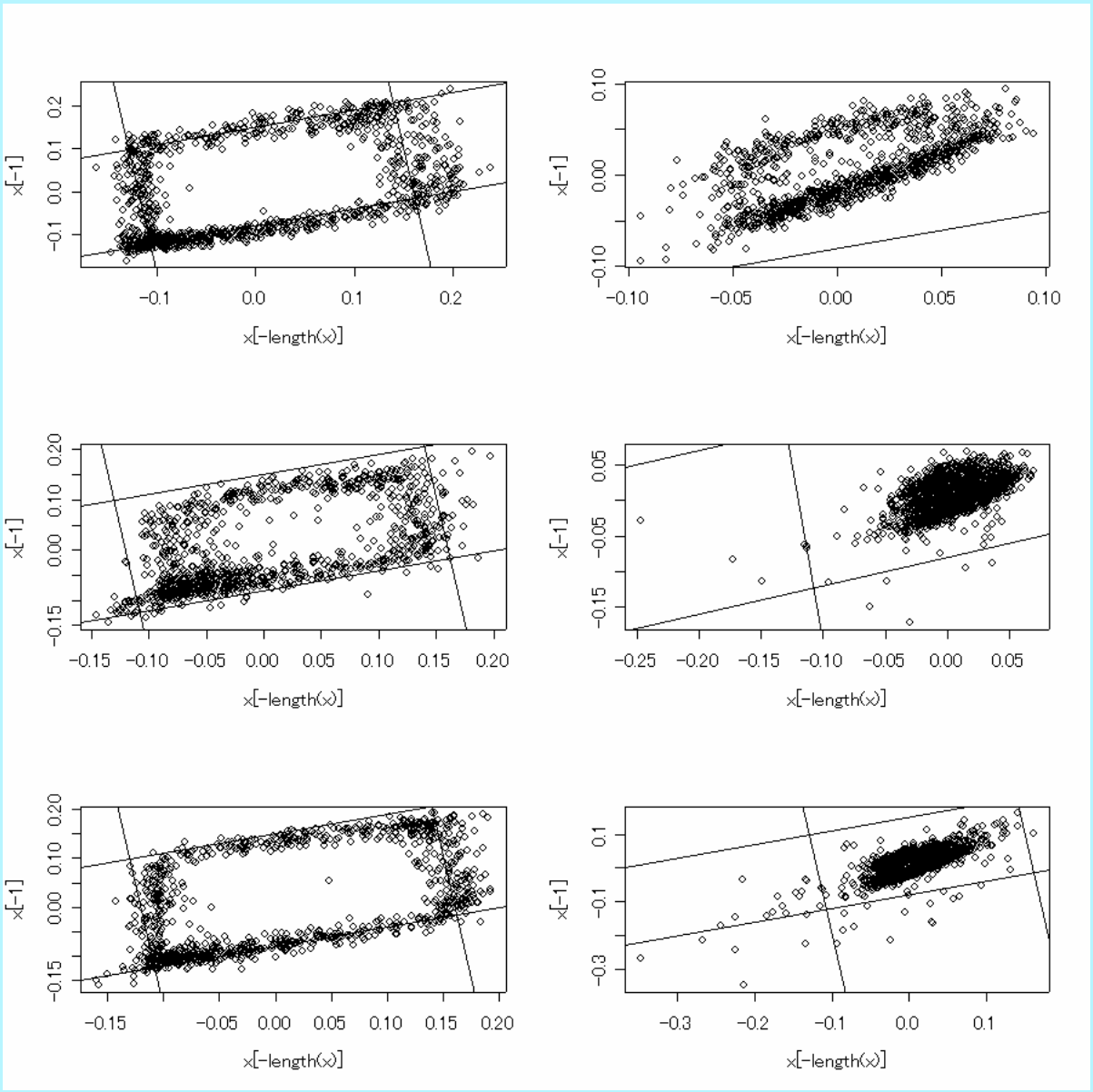
$X_{t+0.5}$

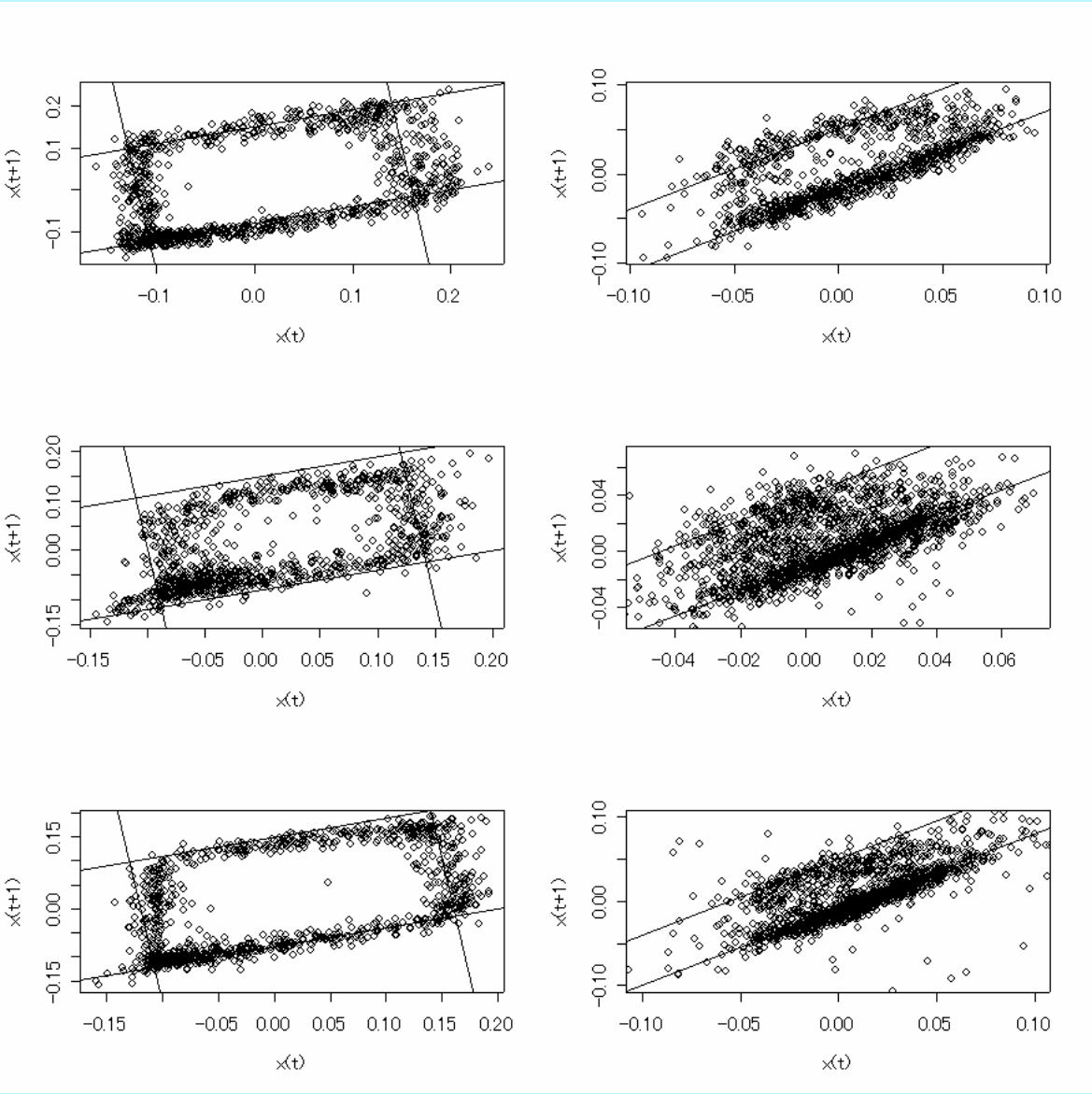


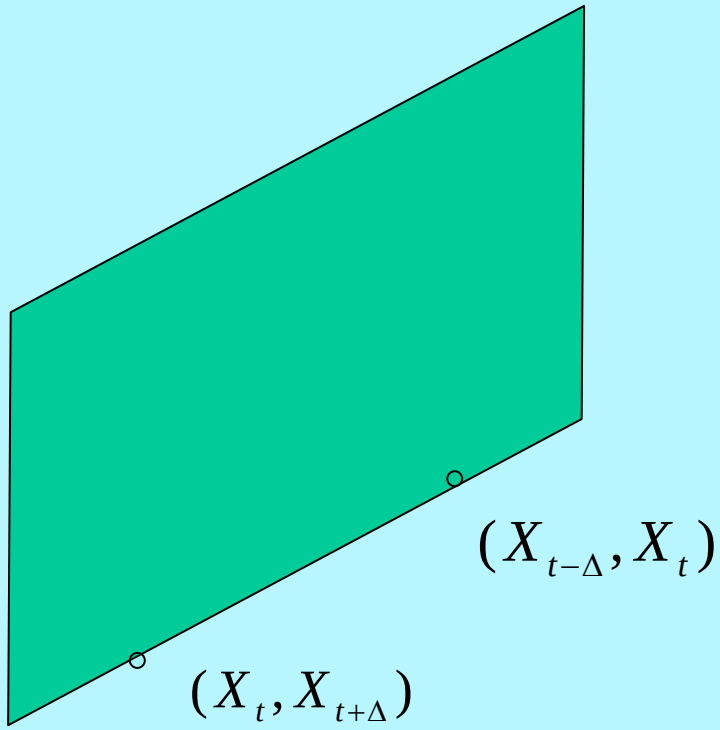
X_t


yy[1:100]
xx[1:100]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.10
−0.05
0.00
0.05
0.10
0.15
①
②
③
④


cos((1:100)/15)
1.0
0.5
0.0
−0.5
−1.0
0
20
40
60
80
100
Index
①
②
③
④


x[-1]
x[-length(x)]
−0.1
0.0
0.1
0.2
−0.10
−0.05
0.00
0.05
0.10
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
0.20
−0.25
−0.20
−0.15
−0.10
−0.05
0.00
0.05
−0.3
−0.2
−0.1
0.0
0.1


x(t+1)
x(t)
−0.1
0.0
0.1
0.2
−0.10
−0.05
0.00
0.05
0.10
−0.15
0.15
0.20
−0.04
0.02
0.04
0.06



$$\frac{X_{t+\Delta} - X_t}{X_t - X_{t-\Delta}} = a \quad \Longrightarrow \quad X_t = \exp\left(\frac{\log a}{\Delta} t + b\right) + c$$

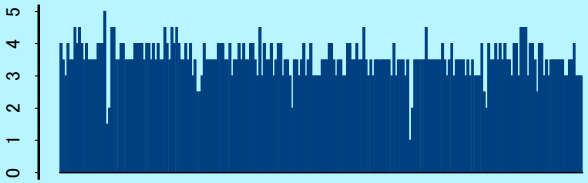
$$a = 0.4\ (\textit{Bad Health}),\ 0.9\ (\textit{Good Health})$$

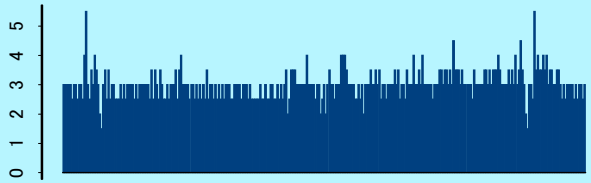
Peak to Peak Time

Bad Health Condition

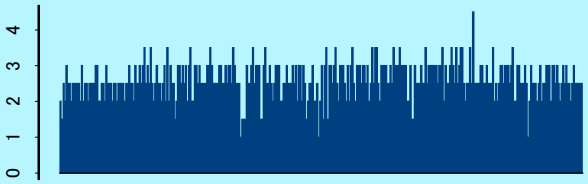
Good Health Condition

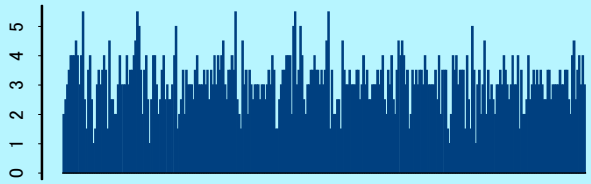
Before Task



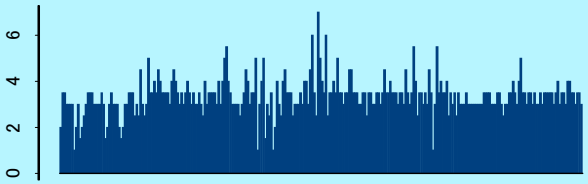


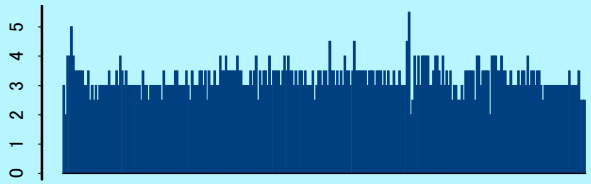
During Task





After Task





Explanatory Model

- Health Condition
  - Amplitude: $\pm 100ml/\sec(Bad),\ \pm 70ml/\sec(Good)$

$$X_t = R\left(\exp\left(\frac{\log a}{\Delta}(t-t_k)\right)-\frac{1}{2}\right) \quad for\ \ t_k < t < t_k'$$

$$= R\left(\frac{1}{2}-\exp\left(\frac{\log a}{\Delta}(t-t_k')\right)\right) \quad for\ t_k' < t < t_{k+1}$$

$a: 0.4\ (Bad),\ 0.9(Good)$

- Task
  - Peak to Peak Time $t_{k+1}-t_k$: $Expectation \approx 3.0\sec,\ \ Variance \uparrow$

Generic Process ?

- Better understanding of the generic process (meta model) of building good models from data for the underlying phenomena concerned
  - Well understanding of the phenomena
  - Find homogeneity
  - Good insight
  - Start from scratch
  - Step by step without prejudice

Models

- Statistical Model
  - Probability Theory
  - Methods
- Data Driven Model
  - Understanding of Data
  - Simple
  - Enough for Promoting Further Investigation (Operational Model)
- Physical Model
  - Fully understandable