INTERNET BASED SYSTEM FOR ADJUSTING CYCLE ERGOMETER WORKLOAD TO MODERATE EXERCISE

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A cycle ergometer is used as several fields including wellness, sport training, and rehabilitation. In order to adjust the cycle ergometer workload, heart rate is generally used. The other factors, however, should be considered to establish moderate exercise. We have combined the information of muscle activity to that of heart rate and proposed a total evaluation pattern using multivariate analysis of several indices estimated from heart rate and myoelectric signals. In this paper, we introduced a fuzzy system to accomplish moderate exercise for an individual person and developed an Internet based system for adjusting the cycle ergometer workload. The fuzzy rules were designed based on the different properties between cardiovascular and muscular activities. We used the Internet technology to achieve on demand support for adjusting the cycle ergometer workload because the workload should be fitted to the individual ability of exercise that probably changes depending on training and physical conditions.

Purpose

Creation of appropriate exercise environment for older adults

Development of training system that adjusts workload depending on the exercise ability of individuals

Problems

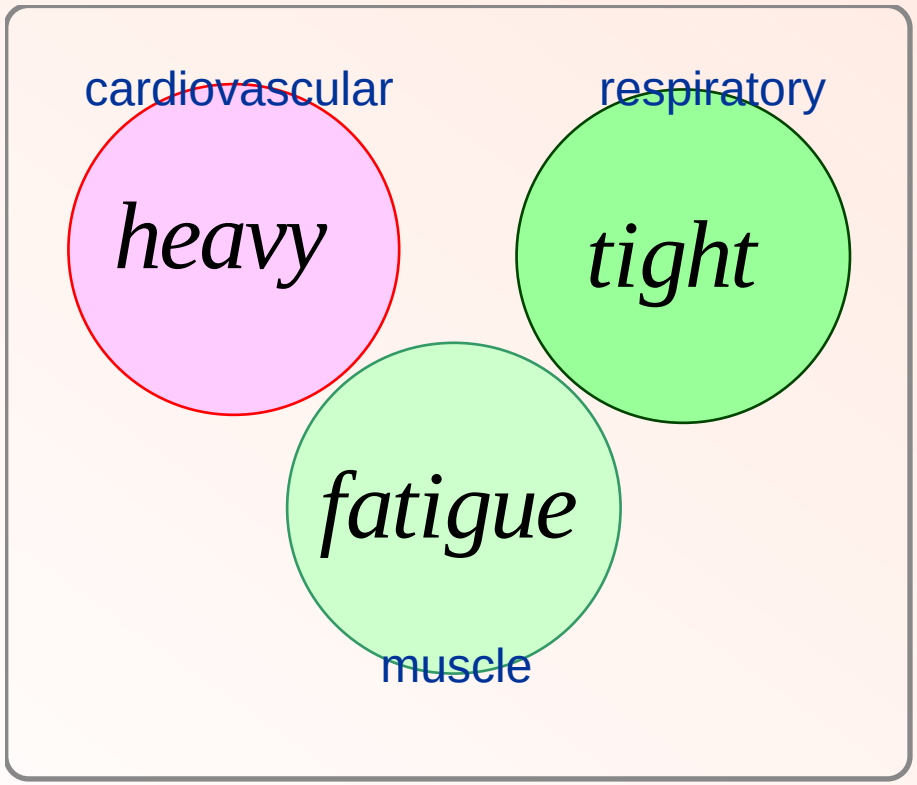
- Large differences in exercise ability
- possibility of overuse
- Low flexibility in exercise ability

Approaches

- Customization of workload control using Fuzzy Inference
- Utilization of computer network

Exercise for Older Person

Sports Physiology



Wellness Environment

21st Century

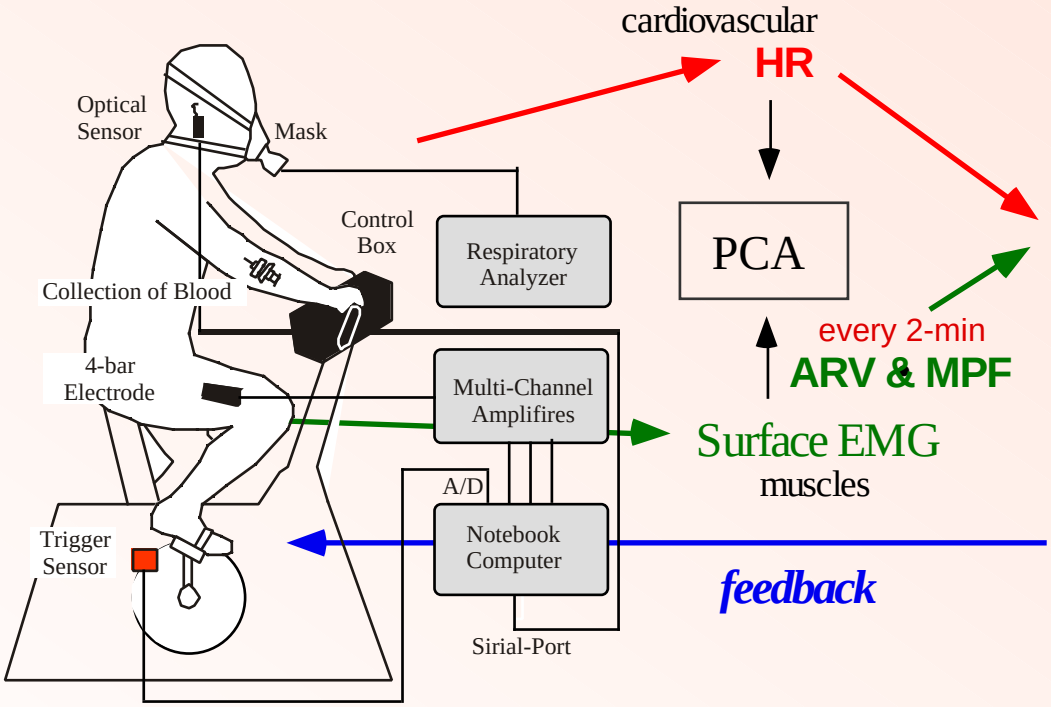
- Increasing population of older person who need exercise for health
- Exercise at anytime and any place

Solutions

- Remote maintenance via the Internet

- PCA and Fuzzy inference for managing functional activities

Workload Control



cardiovascular

HR

PCA

every 2-min

ARV & MPF

Surface EMG

muscles

feedback

Info. for work load control

Fuzzy Inference

Membership functions, Fuzzy rules

Control coefficient

δ $\quad -1 \le \delta_n \le 1$

$$WL_{n+1} = WL_n - \delta_n \, \Delta WL$$

every 5 cycle

WL_{n+1} : workload at (n+1)-frame

WL_n : workload at n-frame

δ_n : control coefficient at n-frame

ΔWL : step-size of workload

Experimental Conditions

- Subjects

  Seven old man and woman (60.0+-6.65years)

- Myoelectric Signals

  muscles: right leg vastus lateralis
  gain: 60dB
  frequency band width: 5.3Hz - 1.2kHz
  4-bar active array electrode

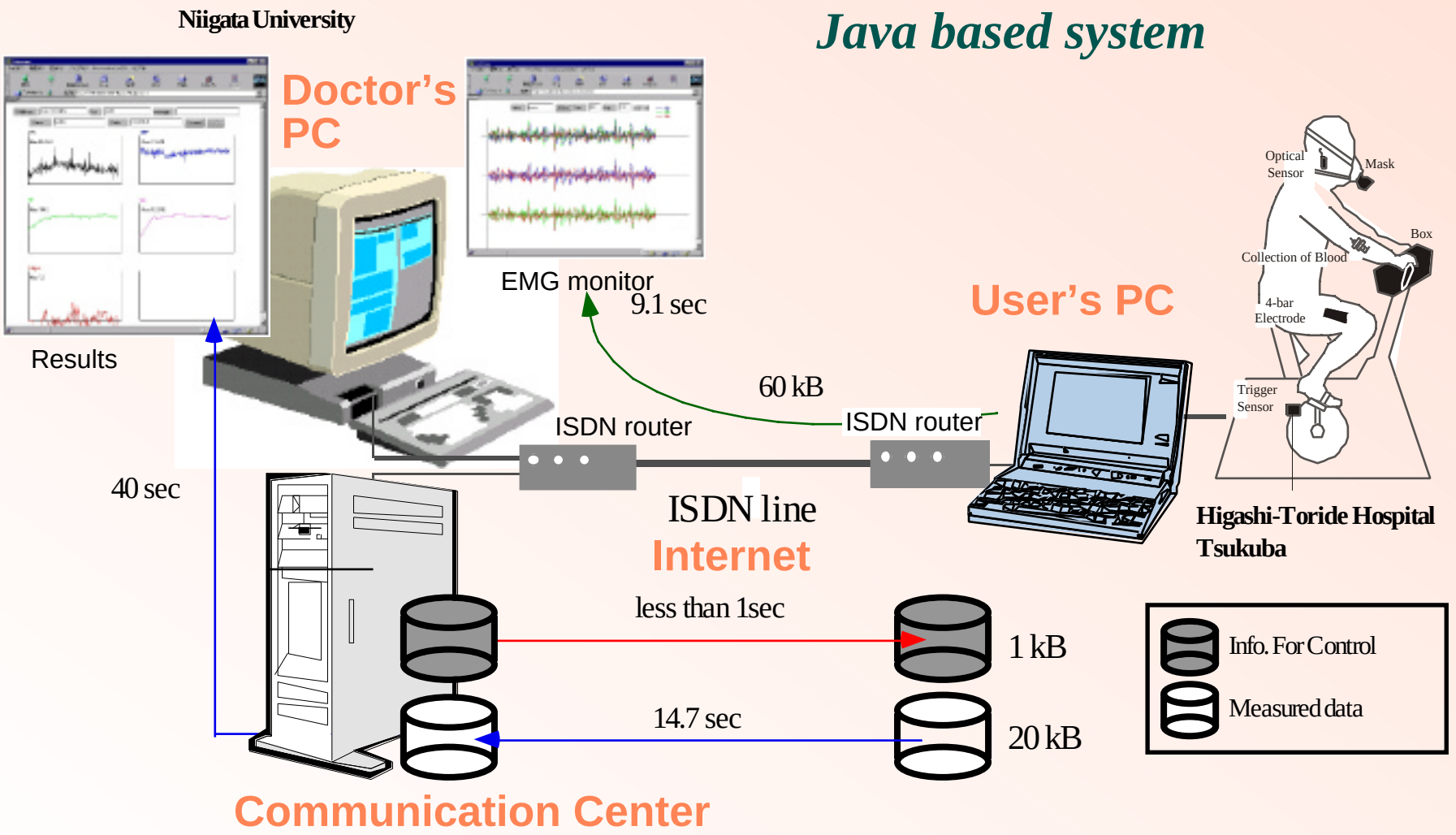
- Heart Rate

  LED-photo transistor

- Metabolism

  Lactate in blood every minute
  respiration gas exchange every minute
  Ratings of perceived exertion (RPE)

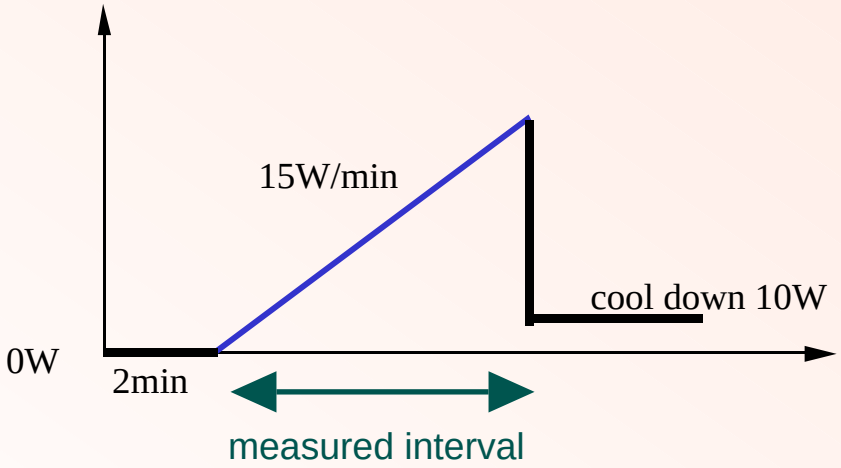
Network System



Experimental Protocol

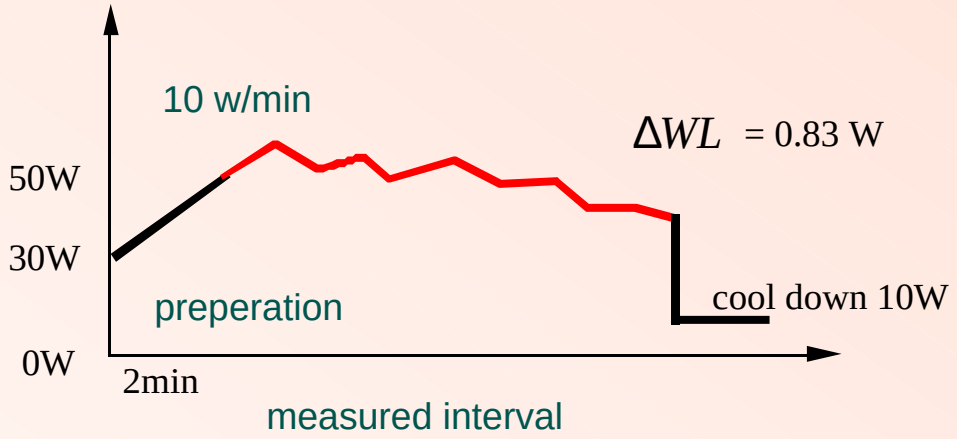
progressively increasing workload

trial for desining Fuzzy inference



controlled workload

control by referring cardiovascular and muscular activities

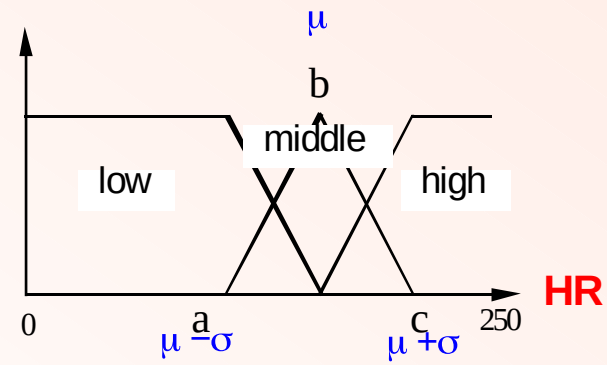


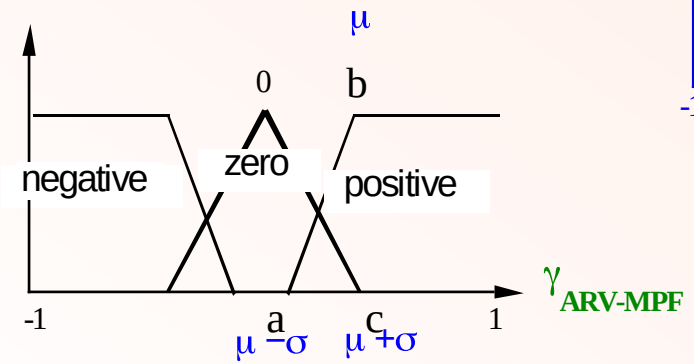
$$WL_{n+1} = WL_n - \delta_n \ \Delta WL$$

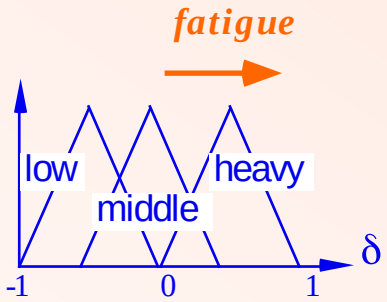
cycle ergometer exercise at 60 rpm

Information for Control

Fuzzy Membership Functions







Fuzzy Rules

γ ARV-MPF

HR	Po	Ze	Ne
Mi	Lo	Mi	He
Hi	Mi	Mi	He

HR	δ
Lo	Lo
Mi	Mi
Hi	He

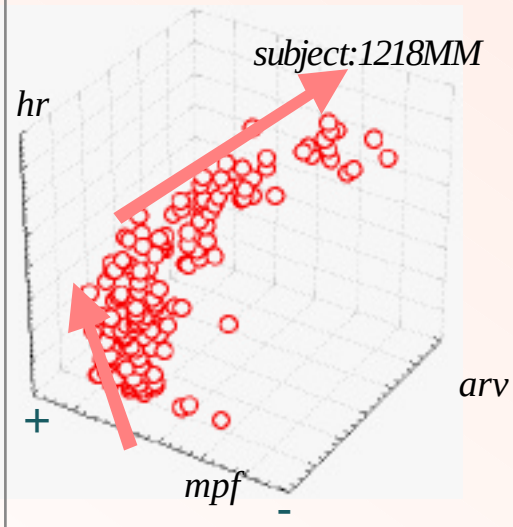
HR
Lo: low
Mi: middle
Hi: high

γ ARV-MPF
Po: positive
Ze: zero
Ne: negative

δ
Lo: low
Mi: middle
He: heavy

Results during Exercise at PW

Type-A 2/7

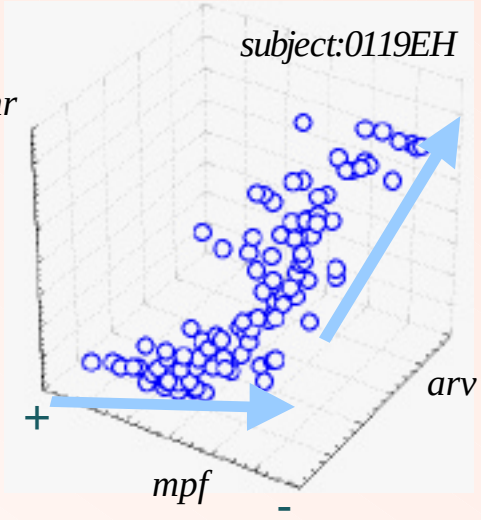


normalized pattern

- same as young adults
- relatively long endurance time
- slim

AT: 80 watt, 105 bpm, RPE: 8 ;
LT: 105 watt, 113 bpm, RPE: 10

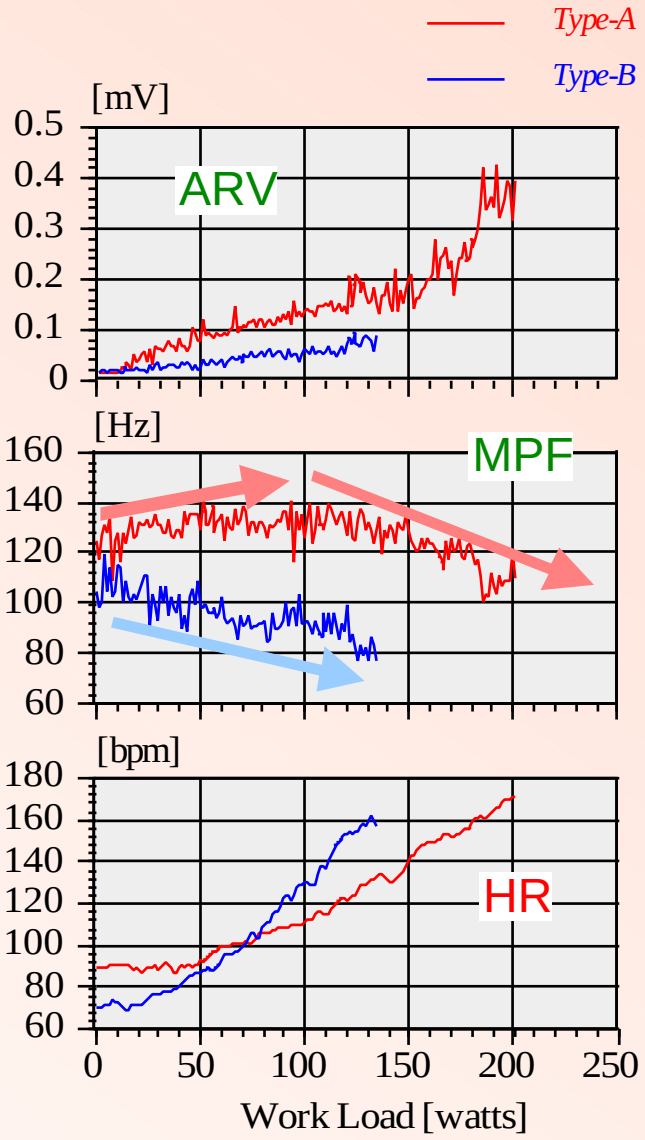
Type-B 5/7



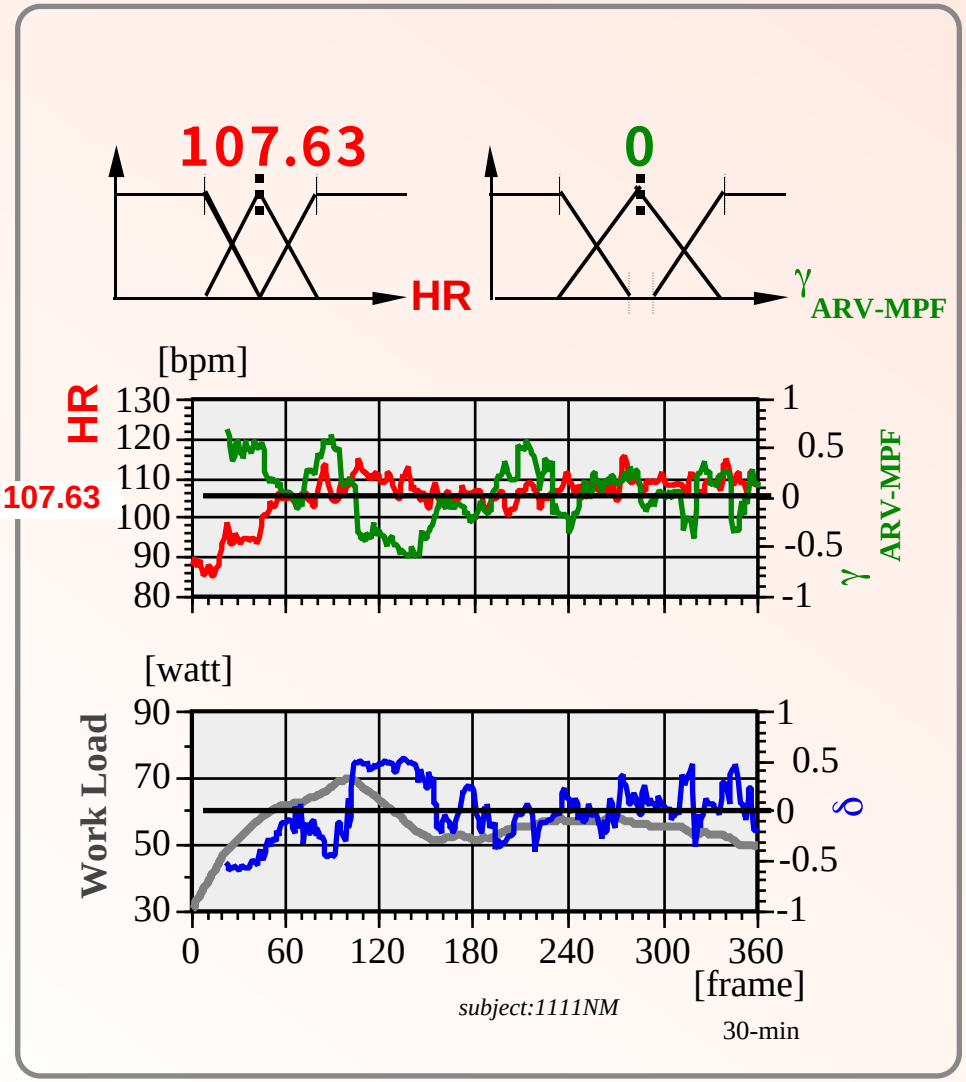
normalized pattern

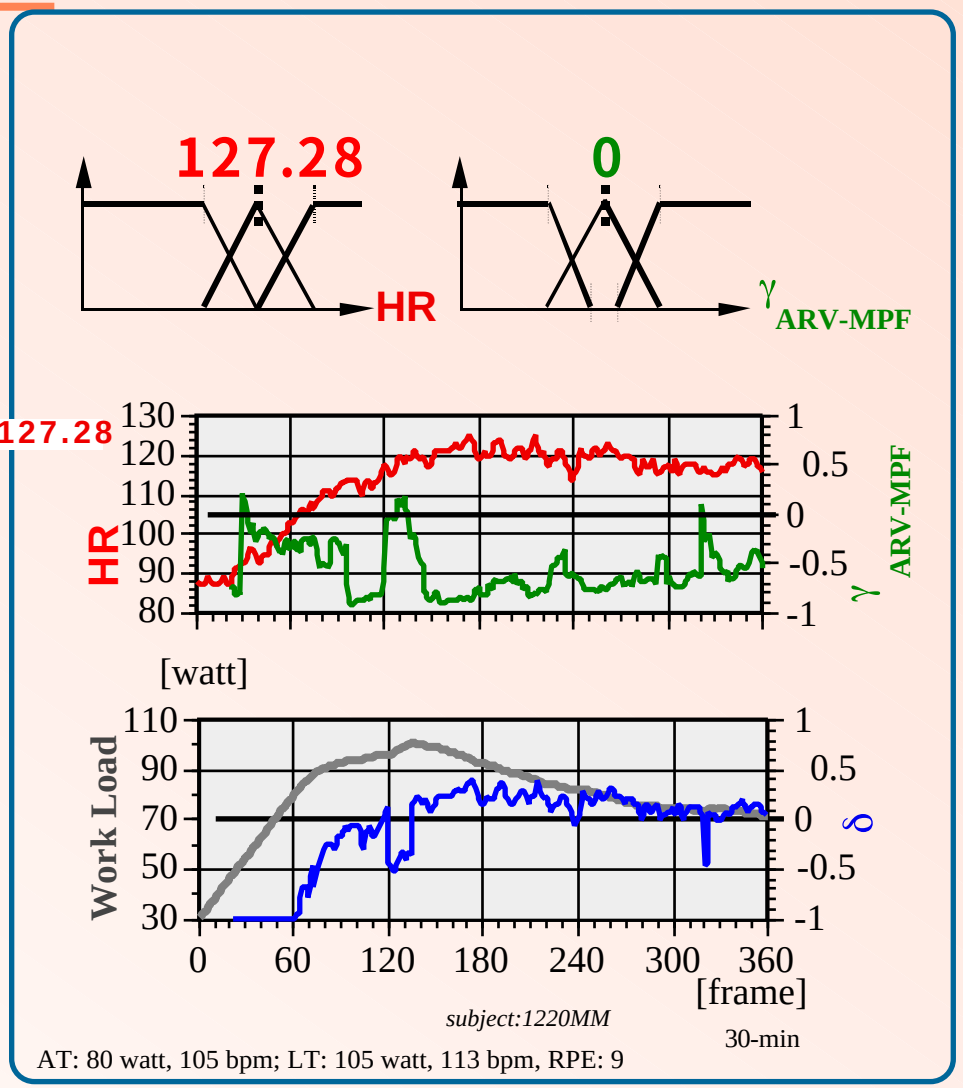
- different from young adults
- short endurance time
- fat

AT: 70 watt, 110 bpm, RPE 12;
LT: 90 watt, 128 bpm, RPE: 13



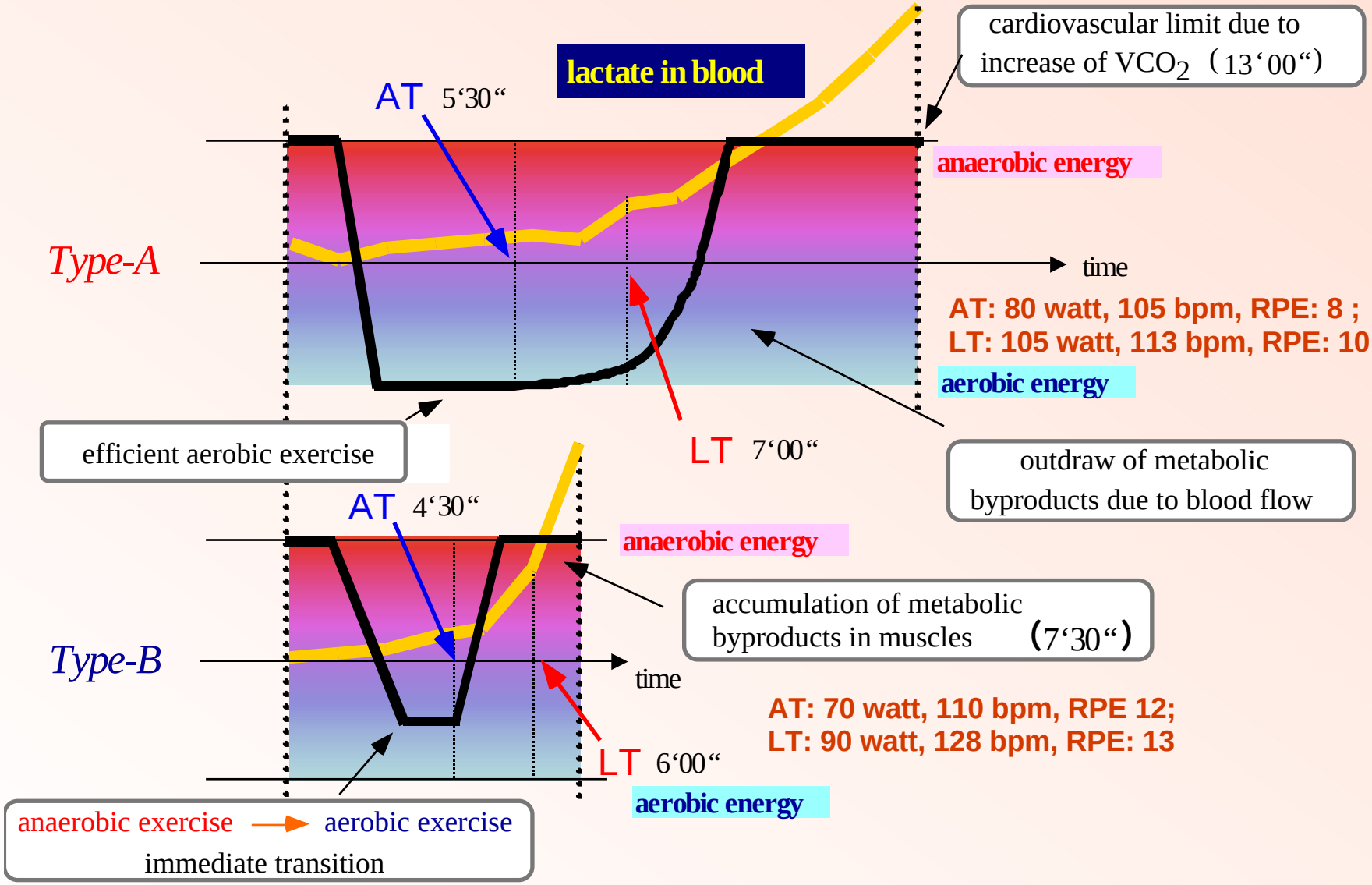
Results during Exercise at CW





AT: 80 watt, 105 bpm; LT: 105 watt, 113 bpm, RPE: 9

Energy Metabolism and Exercise



Conclusions

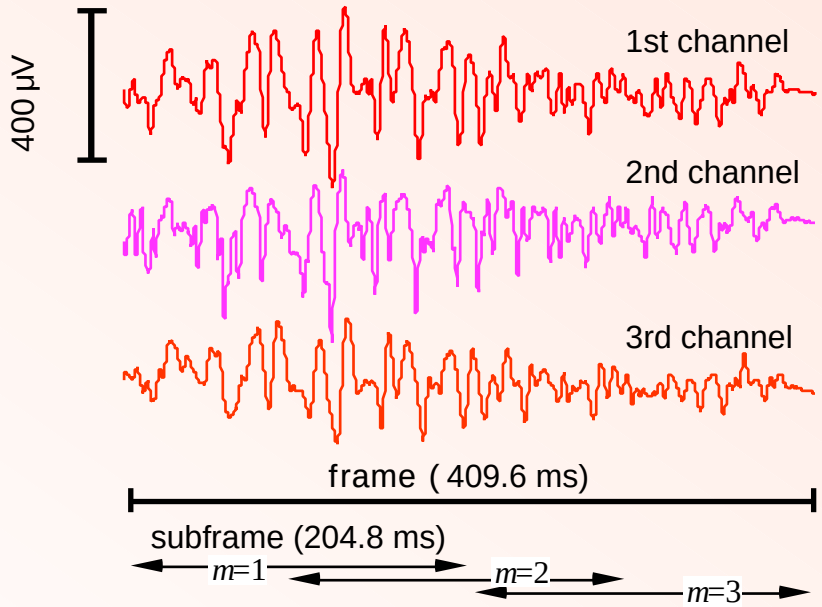
- Workload control for older adults
  - workload control based on cardiovascular and muscular
  - customization of workload for individuals
- Internet system for remote maintenance
  - multi-platform network program by Java
  - field experiments using ISDN line

Next step

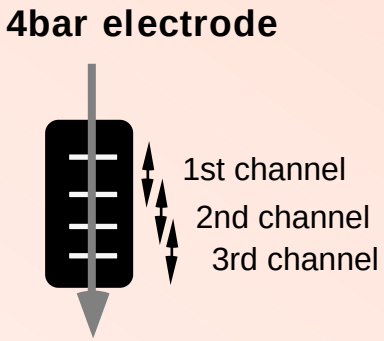
- Classifing fuzzy membership functions and rules
- Design of appropriate control scheme for type-A and B
- Adjusting control timing depending on time-varying behavior of biosignals

Key Technology (1)

EMG Measurement duirng Dynamic Contractions



one frame = 409.6 ms, one subframe = 204.8 ms



Estimation of ARV & MPF at time *n*

$$arv_m = \max\left\{arv_m^{(ch)}\right\}_{ch=1}^{ch=3}$$

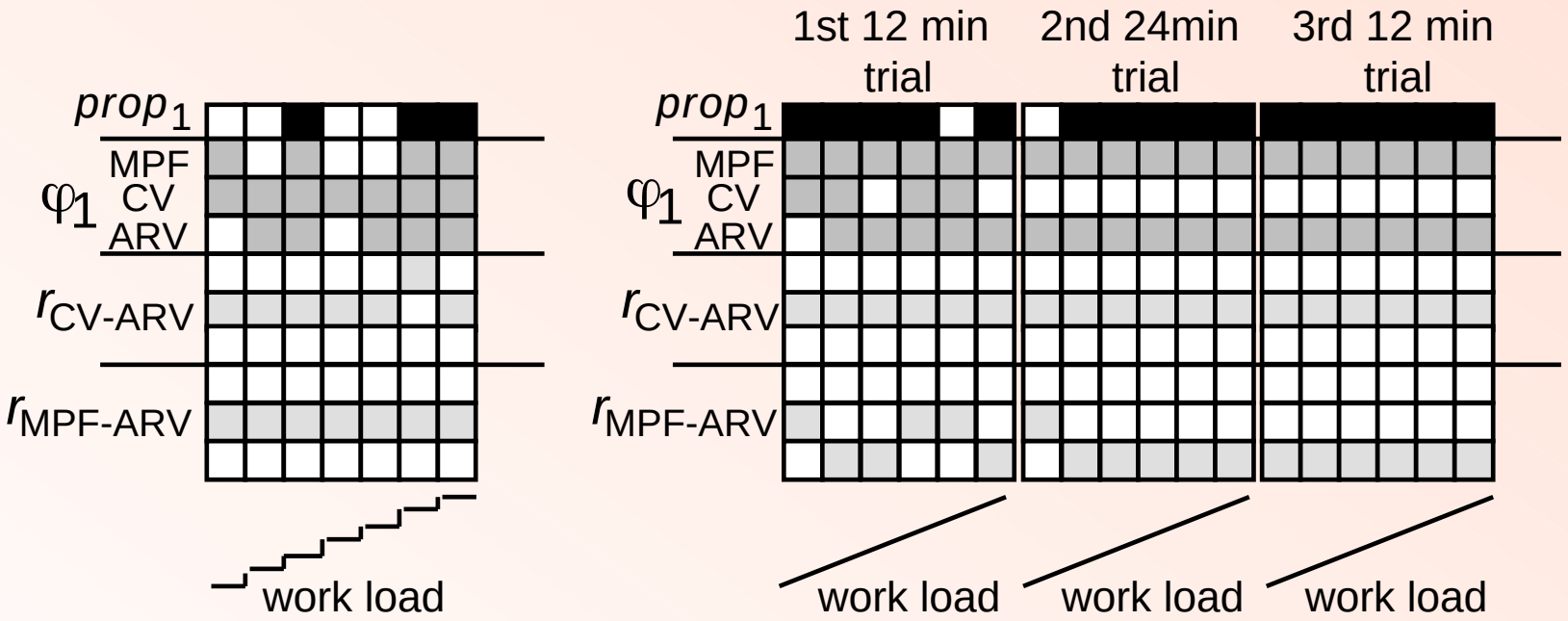
$$arv_n = \frac{1}{3}\sum_{m=1}^{3} arv_m$$

$$mpf_m = \min\left\{mpf_m^{(ch)}\right\}_{ch=1}^{ch=3}$$

$$mpf_n = \frac{1}{3}\sum_{m=1}^{3} mpf_m$$

Key Technology (2)

Evaluation of Functional Activities during Exercise



■ proportion of z_1

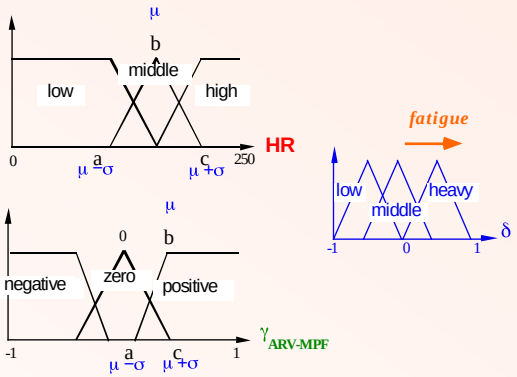
□ correlation coefficients

□ absolute values of φ_1 components

Key Technology (3)

Fuzzy Inference & Internet for Customization

-Fuzzy



γARV-MPF / HR	Po	Ze	Ne
Mi	Lo	Mi	He
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HR	δ
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HR
Lo: low
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γARV-MPF
Po: positive
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δ
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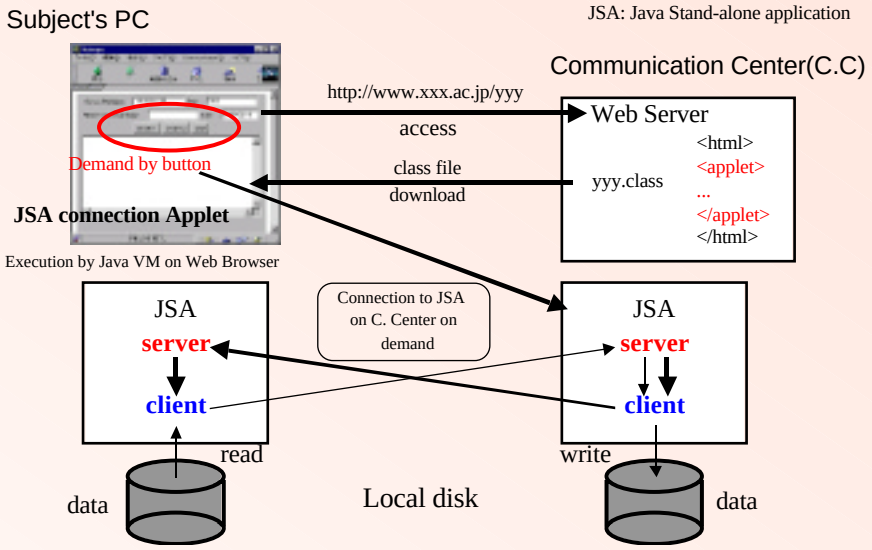
- Internet



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Change in Exercise Ability due to Aging

- **Degeneration of flexibility**
  Narrowing working range for elbow, knee, whist joints

- **Weakness of dynamic power**
  Degeneration of neuromuscular system

- **Effects of exercise**
  Improvement of neuromuscular system reactions, but less growth of muscles

- **Change in muscle fiber composition**
  Fast-twitch fibers are easier to be degenerated than slow-twitch fibers.
  endurance training