RITSUMEIKAN

Special Lectures（特殊講義）

Soft Wearable Devices and Their Applications

ロボティクス学科　教授

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Futurize.
きみの意志が、未来。

We have some Pair work

Pair them up in twos or threes.

Rules

◆ To be paired with an international student and a Japanese student.

◆ Pairing students who are not in the same laboratory.

◆ Discussions must be in English.

◆ Worksheets must be written in English.

*You can download the worksheet file (word or pdf) from Manaba+R report box.

* Reports must be submitted electronically via Manaba+R report box.

Soft Robotics for Human

Soft Wearable Devices and Their Applications

We need

Biomedical applications of soft,wareable sensors.
e.g. Bending sensors, electrodes for nerve potentials, streching sensors

Why we need Soft Robotics techniques?

Soft Robots for Human

Q1: Why do we need soft robots?

-The robot itself must be soft in order to interact with people.

Palo

NICOBO

LOVOT

Visit Here!

https://robotsguide.com/

Soft Robotics for Human

“Soft robotics" is important in the research field of Biomedical Engineering.

We do not have good interaction,,,

sensors

Know the status

Control Something

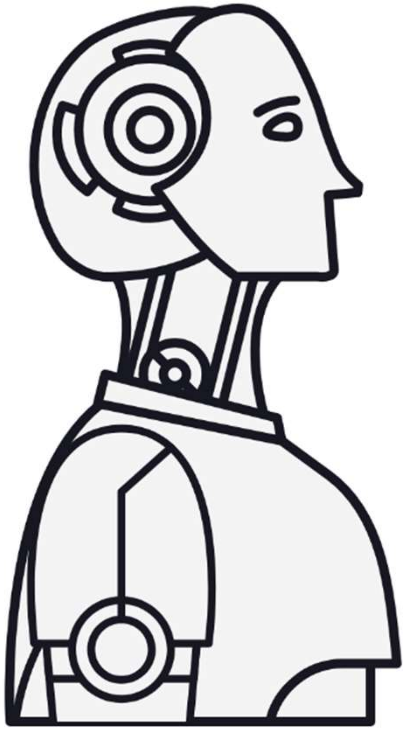
Human

Robot

actuators

Soft Sensors

Q2:Why do we need soft sensors?

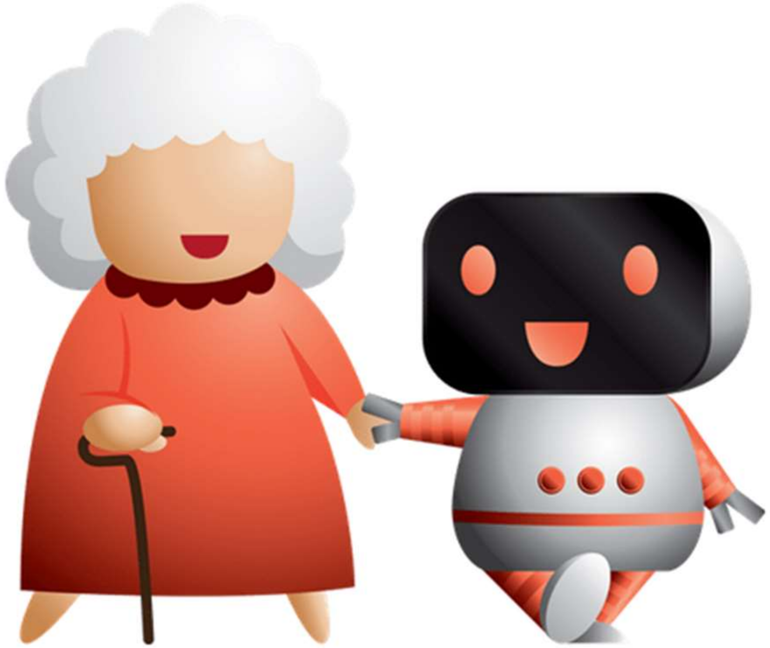


Robot vs Human

Soft Actuators

Q3:Why do we need soft actuators?

Considering the caregiving scene.
What is required for a robot to act on a person?
(Both of Mental & Physical)



Soft Robotics for Human

Why do you think "soft robotics" is necessary Biomedical engineering research?

■Sensor

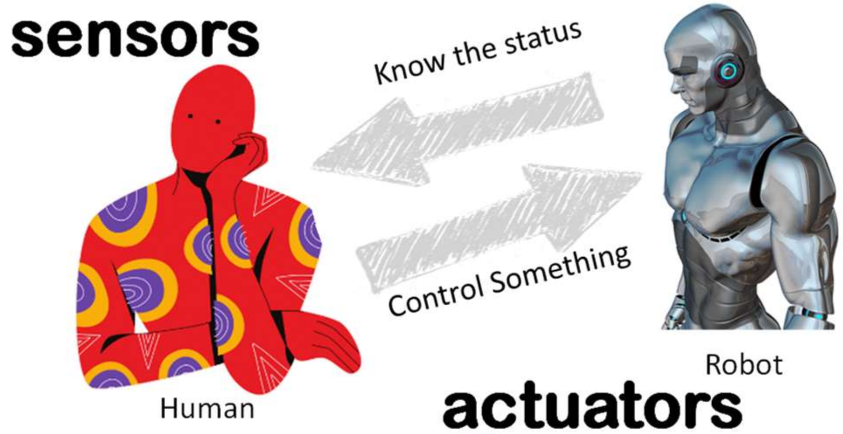
In order for a person to control the robot or for the robot to help the person, the robot needs to know the person's condition

⇒Sensors that measure the human condition

■ Actuator

Robots act on a person's psyche, assist in movement, or physically work on a person's physiology to change that state, depending on the person's condition.

Soft sensors & actuators



For Example…

CYBATHLON

There are eight competition disciplines: brain-computer interface (BCI), functional electrical stimulation bike, electric prosthetic hand, electric prosthetic leg, exoskeleton race, assisted robot, visual aid and electric wheelchair.

electric prosthesis

BCI


exoskeleton race


visual aid


assist robot

Functional electrical stimulation bike


electric wheelchair

electric artificial arm

Table of Contents for Today's Lecture

1. Sensors that measure human physiology
   (Mental and physical)

2 .Sensors that measure human motion and movement

3. Actuators that act on human physiology

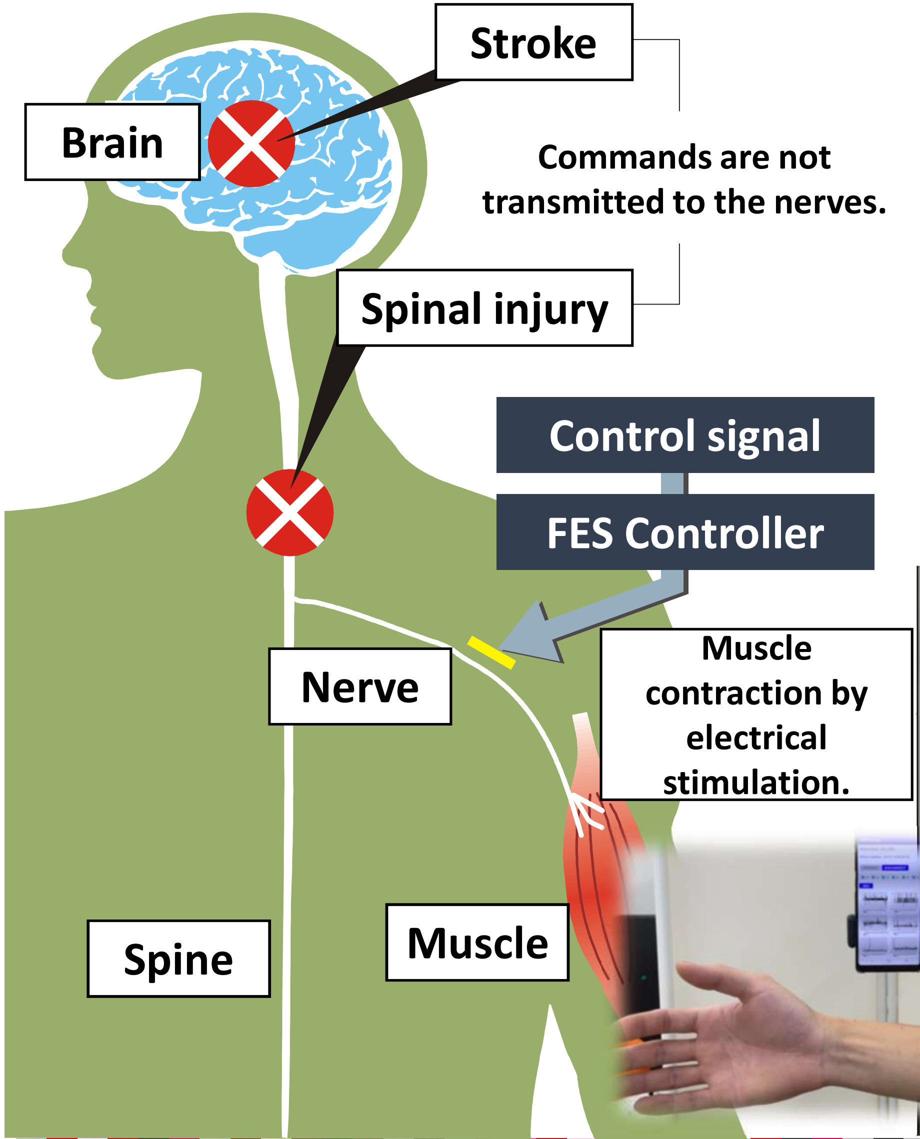
1. **Sensors that measure human physiology** Q4 Part
   (Mental and physical)

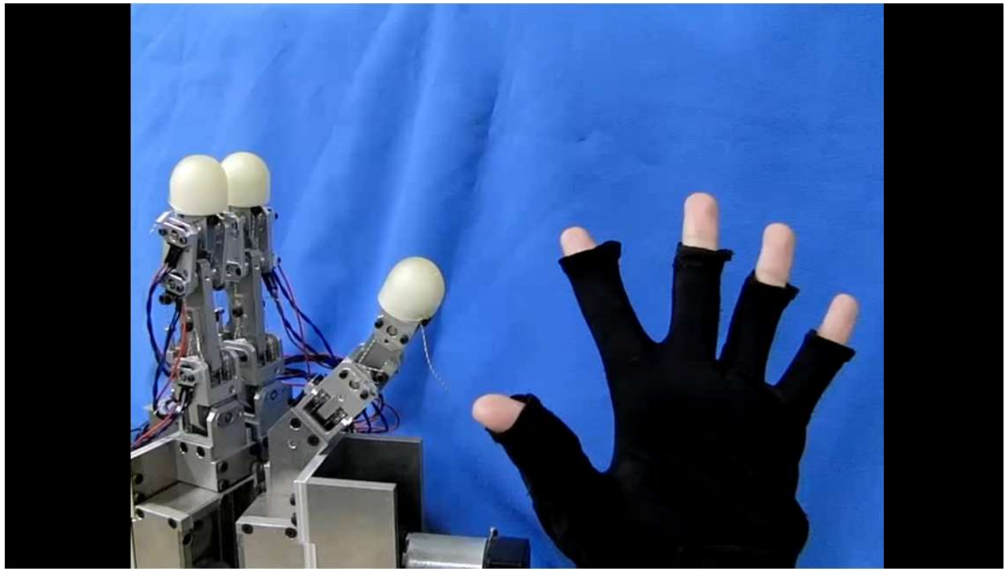
2 .Sensors that measure human motion and movement

3. Actuators that act on human physiology

Why we need?

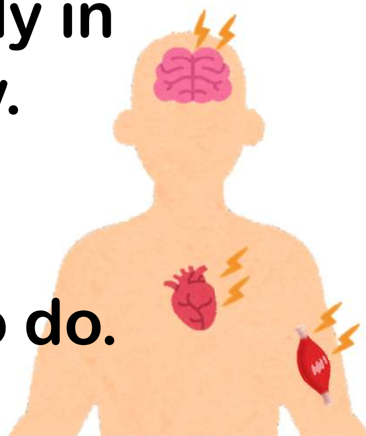
What are bioelectrical signals?

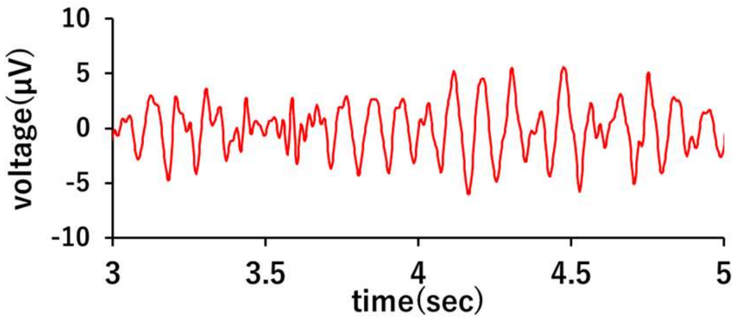




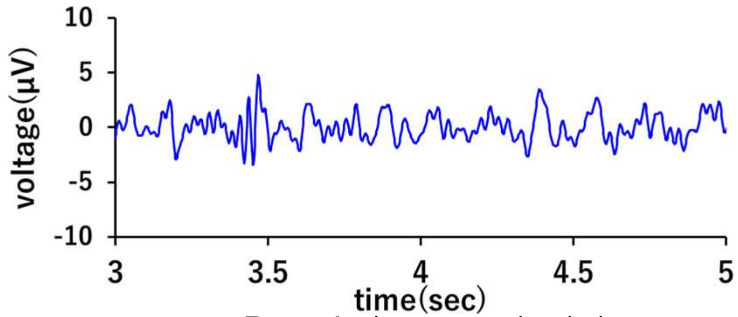
Biosignal of human body

- bioelectrical is generated by the human body in response to the physical and mental activity.
  - ✓ Brain, heart, muscle, etc.
- This biosignal changes with your thought, intention, feeling, and what you are trying to do.





Brain's biosignal while relaxing in chair

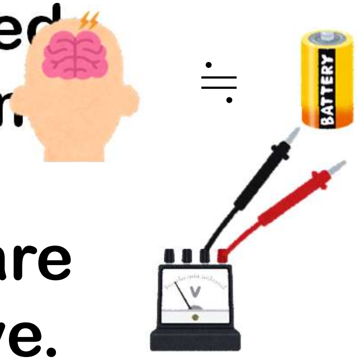


Brain's biosignal while thinking about something

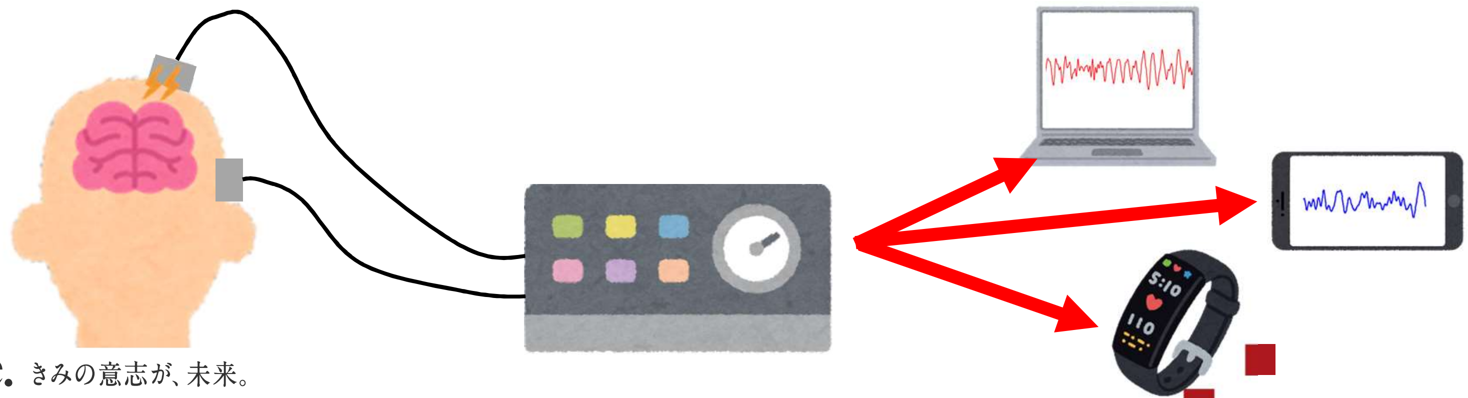
- It is possible to know your thought, intention, feeling and what you are trying to do, by measuring biosignal of human body.

Method to measure bioelectrical signals

- The biosignal of human body can be considered same as battery, and it can be measured in sa way as battery.

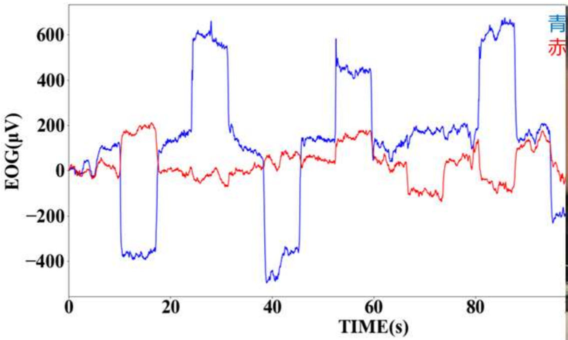


- Two metal plates, that is called “electrodes”, are attached on the skin using conductive adhesive.
- These electrodes are connected to the measurement device, and biosignal can be measured.
- Measured biosignal can be displayed on various devices.
  - ✓ Personal computer, smartphone, smartwatch, etc.



How do the robot obtain the information of human?

Stress	Electro-Cardiogram	ECG	100μ～10m	0.08～100
Think, Emotion	Electro-Electroencephalogram	EEG	1μ～100μ	0.1～30
Move,Intention	Electro-Myogram	EMG	1μ～10m	2～2000
Move,Think	Electro-Oculogram	EOG	0.1m～0.5m	DC～200
Stress	Cutaneous electric reflex	SSR	0.1m～5m	0.03～15



Measurement

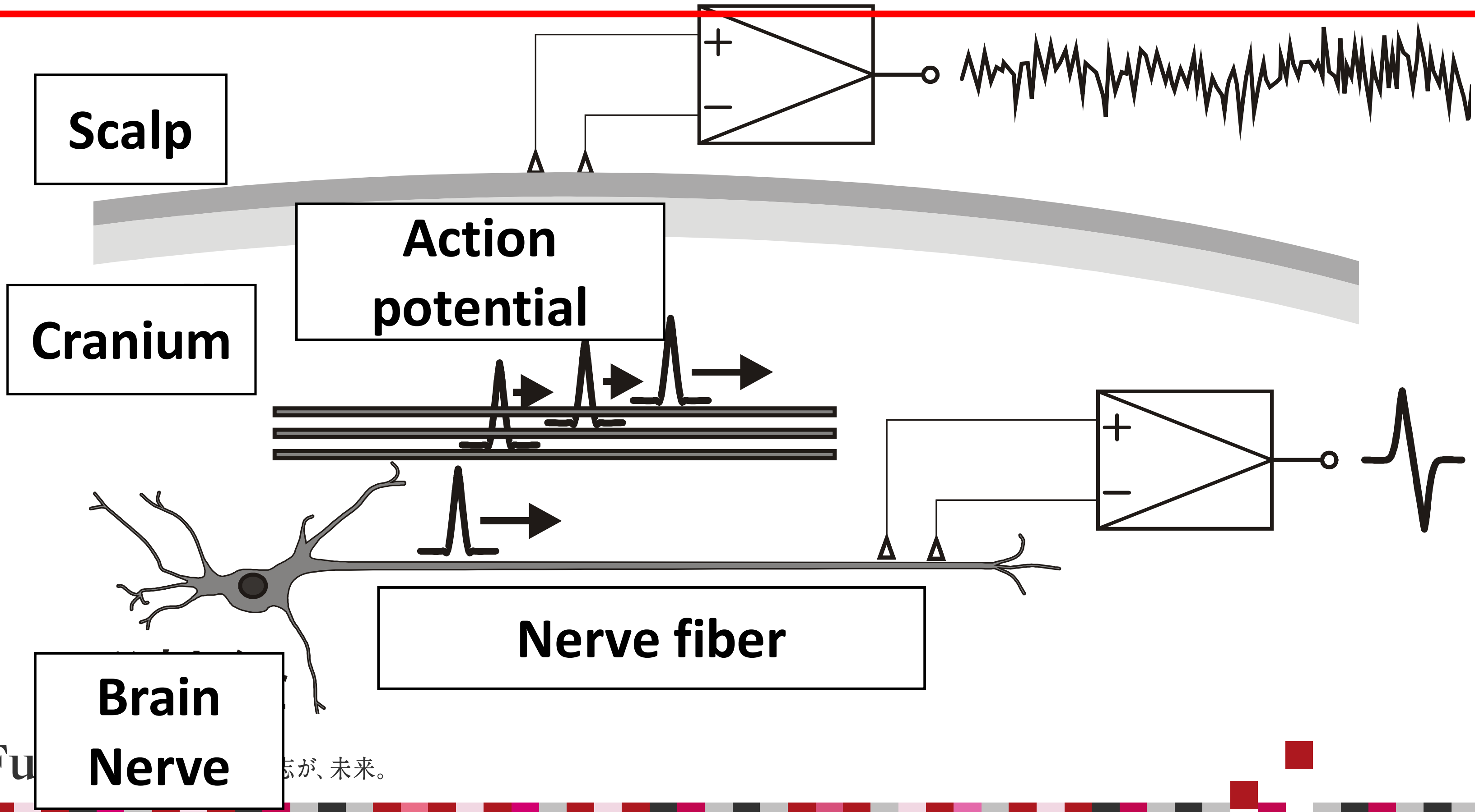
【Easy】 ECG: Electrocardiogram

【Easy】 EMG: Electromyogram （s-EMG⇒ surface EMG）

【Hard】 EEG: Electroencephalogram

For Example Electroencephalography

EEG = changes in electrical potential at the epidermis of the head, where the electrical activity of individual nerve cells in the brain is aggregated through the skull and skin.

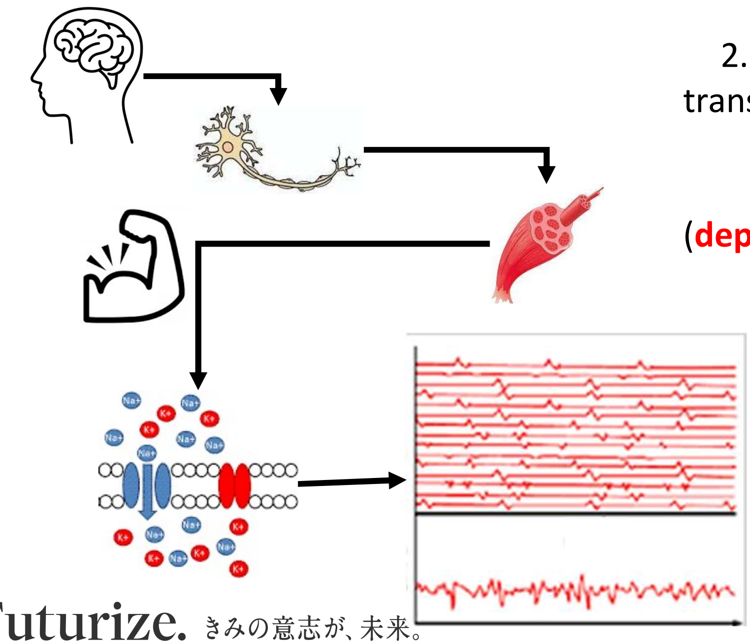


For Example Electromyography

EMG・・・

Myopotentials are action potentials generated by muscle cells in living organisms during contractile activity.
The electromyogram is the variation of the weak electric field generated within that muscle on the vertical axis and time on the horizontal axis.
Myopotentials measured at the body surface are μV to mV and amplified 100-10,000 times.

Why do potentials occur?



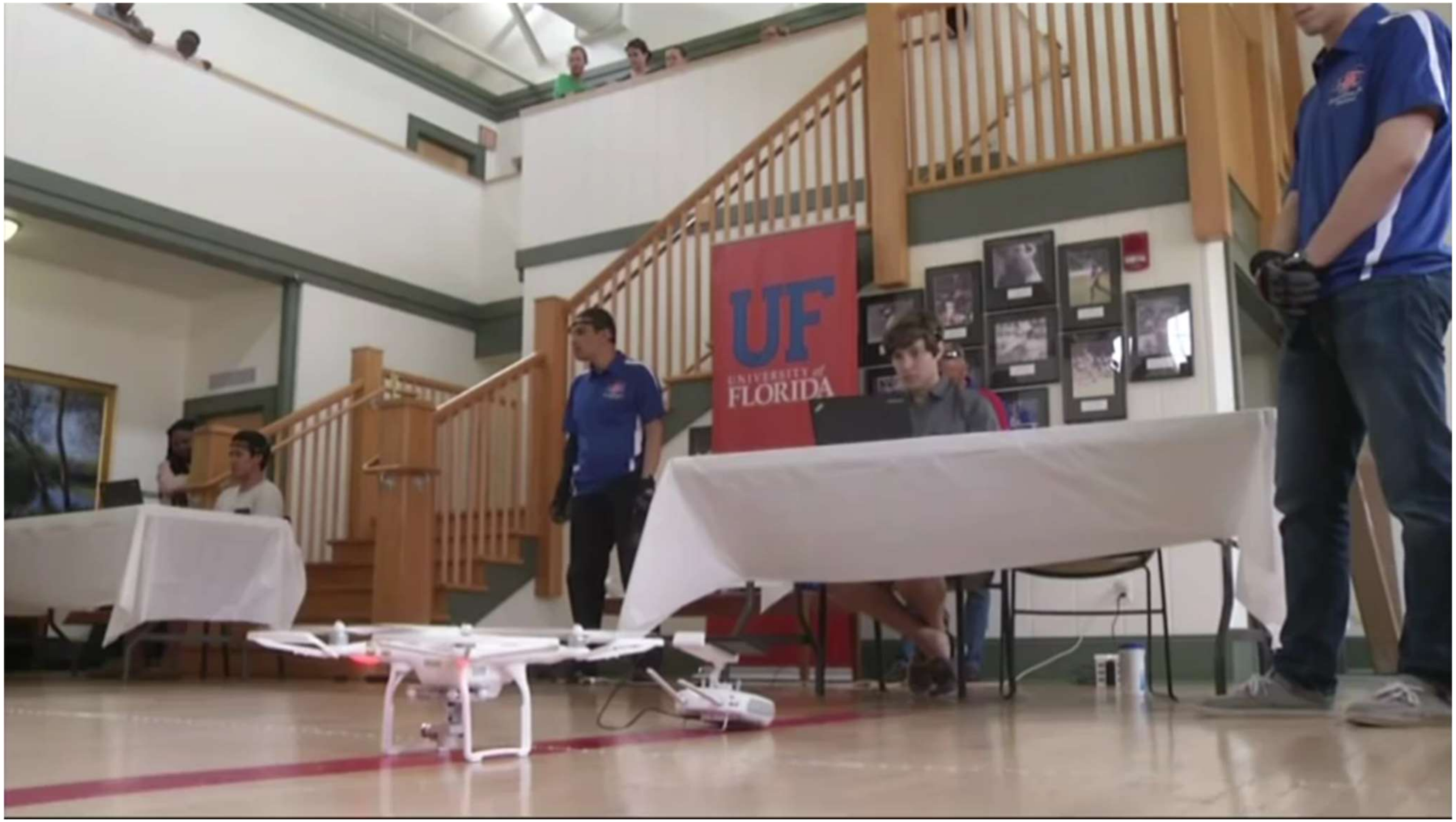
1. firing signals from the brain travel through the nerves to the neuromuscular junction

2. when the firing signal reaches the neuromuscular junction, transmitters are released into the muscle fibres.

3. sodium ions are taken up by the cell by transmitters (**depolarisation**)

4. sodium ions are electrically charged and therefore generate a **potential difference**

BCI Application & Drone



EMG Application for PuyoPuyo

Smart Wear Soft Electrodes

ECG induction method: Unipolar lead to install a device

Lead system: Pseudo lead I between a ground and a different electrode

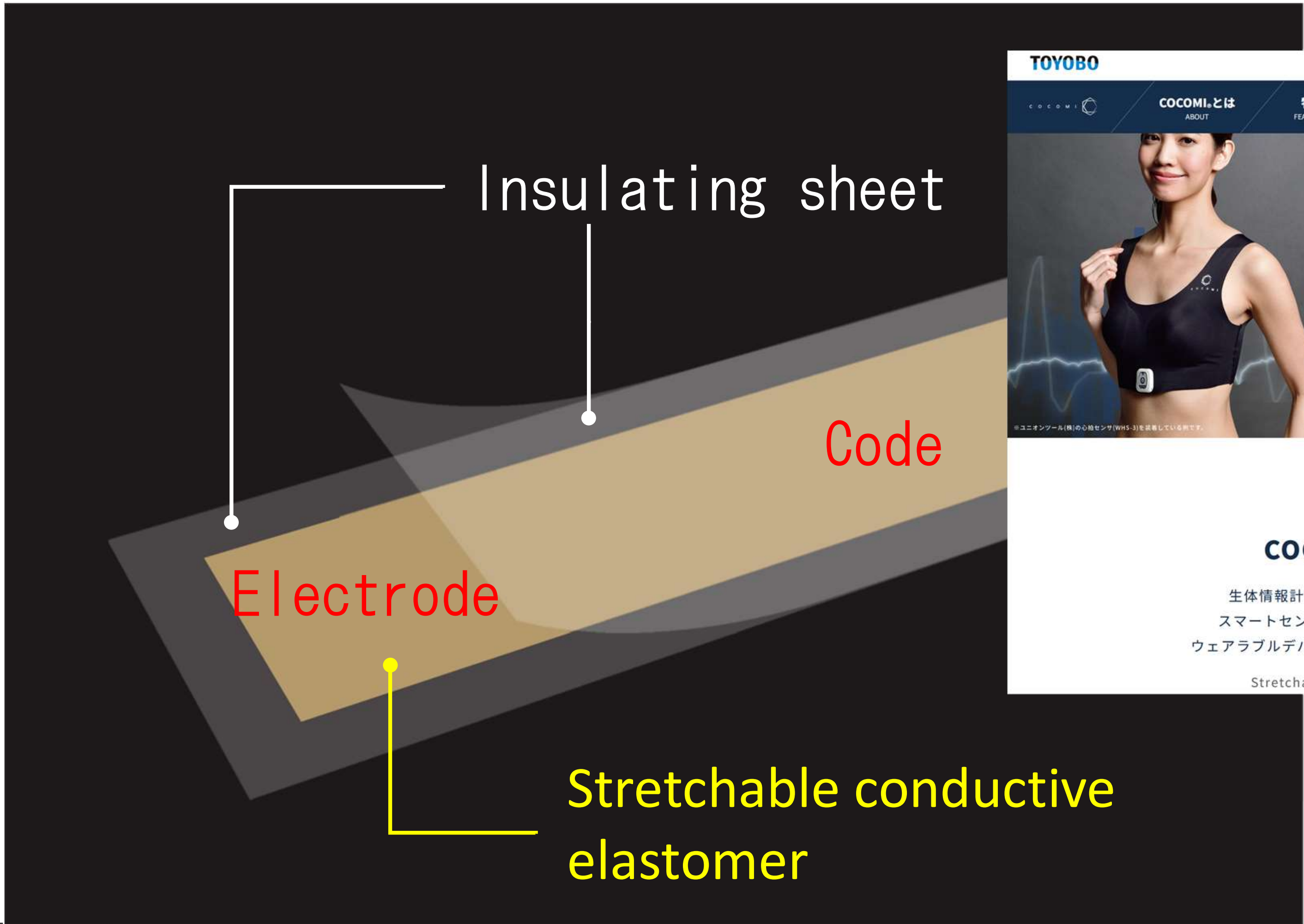
For male

For female

Item	Specification
Name of device	WHS-2
Company	UNION TOOL, Japan
External dimensions	41.0 × 37.5 × 10.0 [mm]
Mass	13.7 [g]
Wireless transmission interval	Every HR

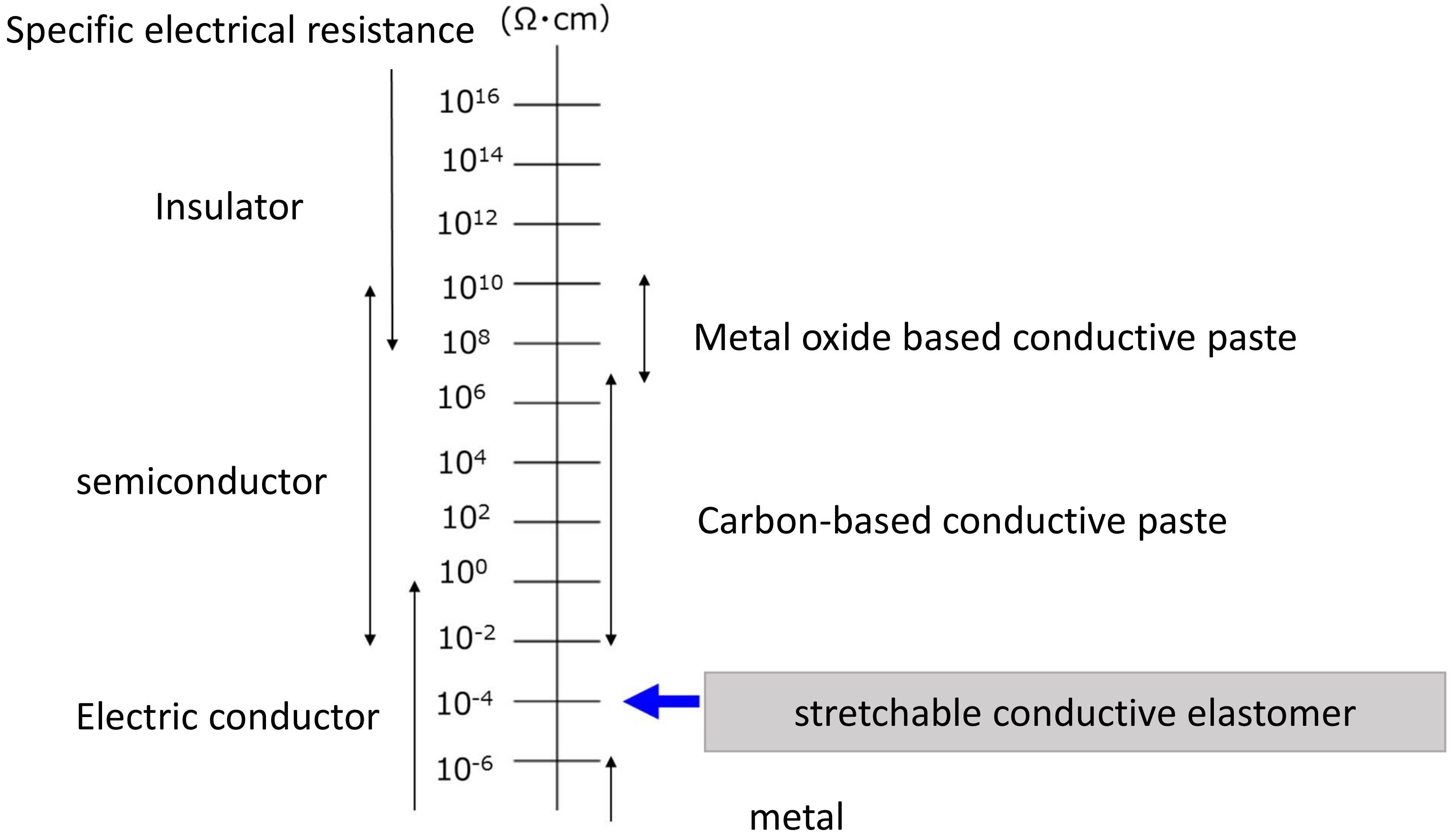
Stretchable Conductive Elastomer

- Sensors (electrodes) and codes ← COCOMI



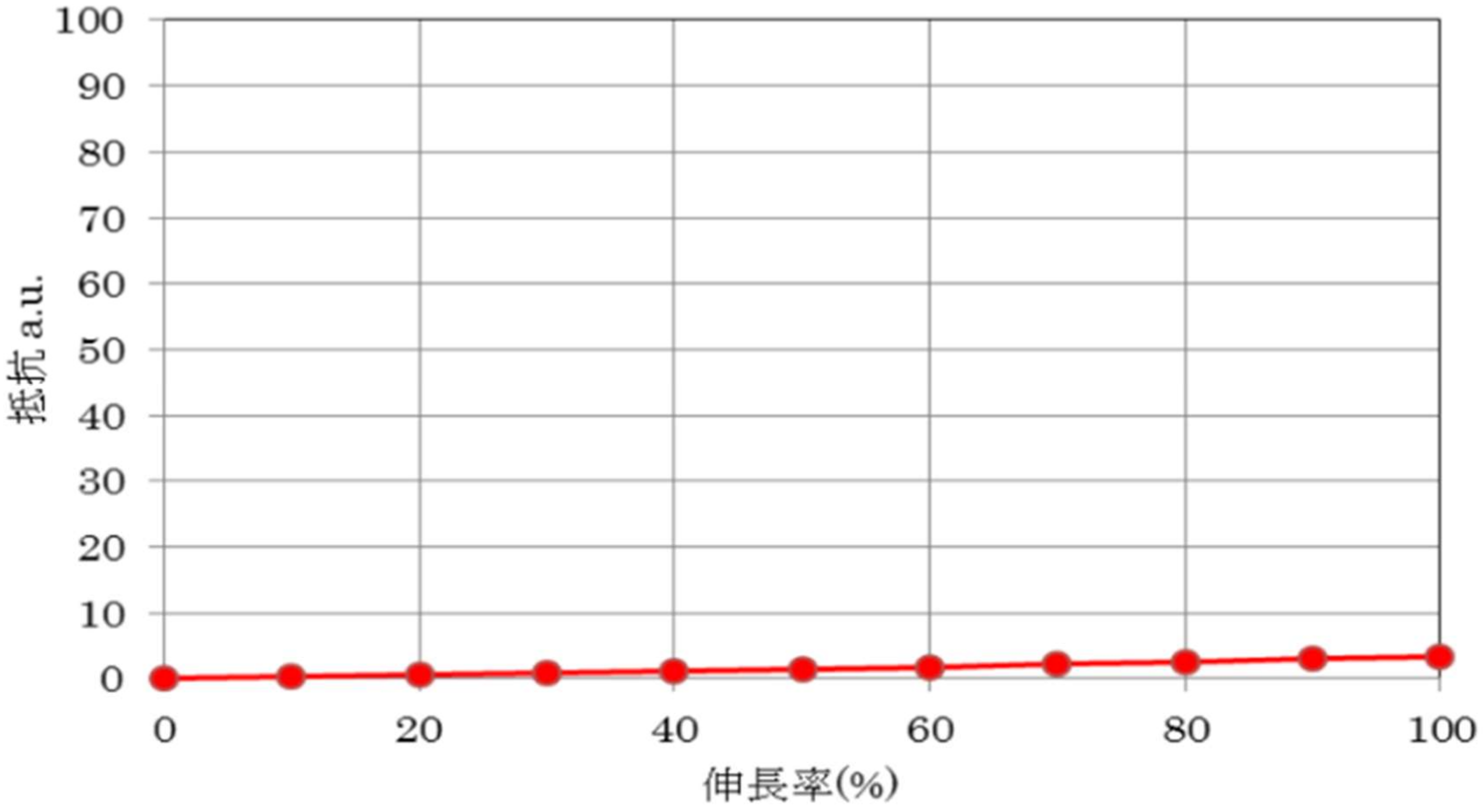
Toyobo
(東洋紡株式会社)

Specific resistance of stretchable conductive elastomer



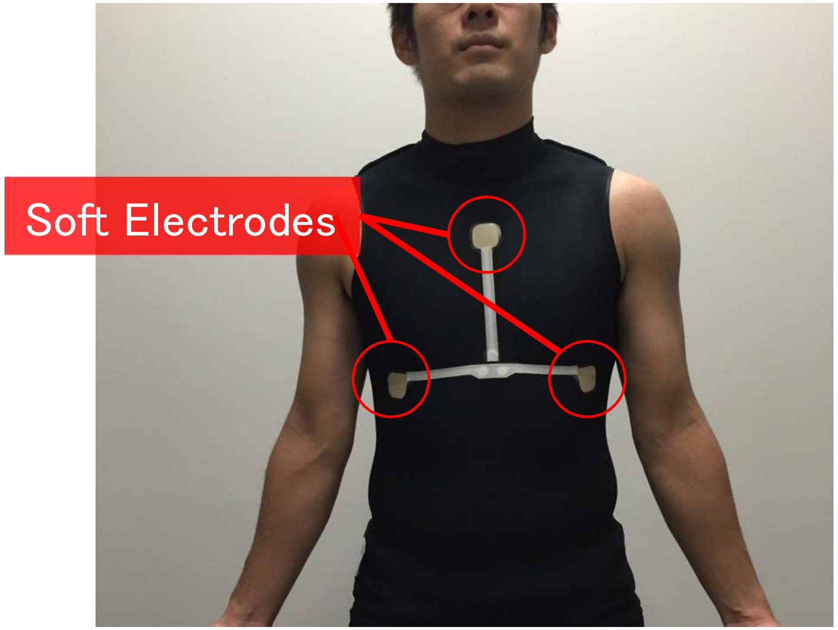
- Specific resistance is very low than others conductive paste.

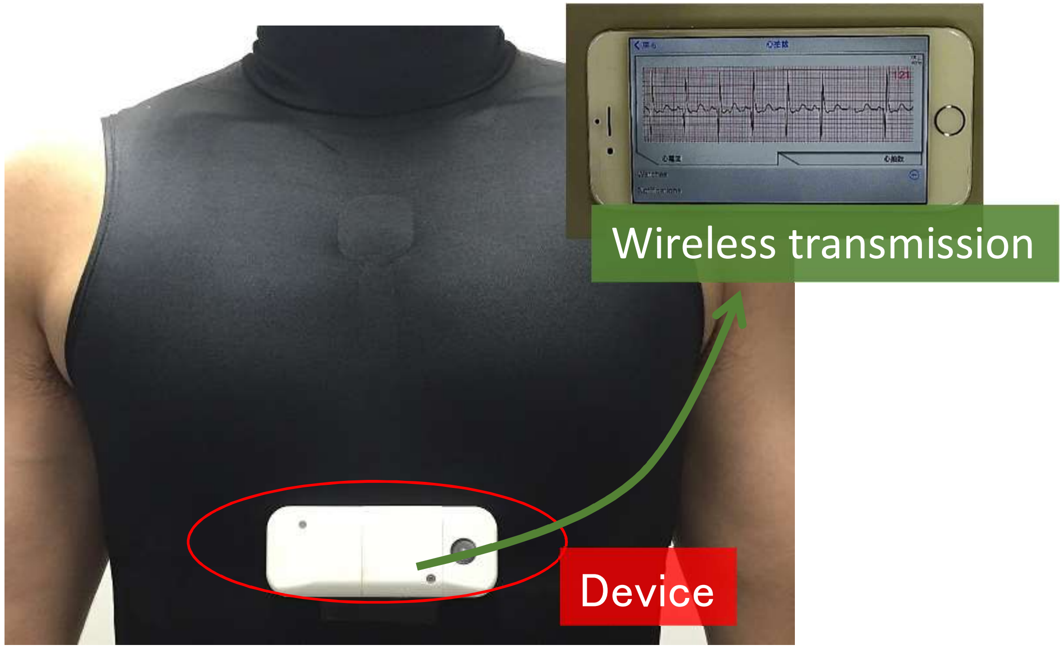
Elongation rate of stretchable conductive elastomer



- Electric resistance is low, even in 100 % elongation.

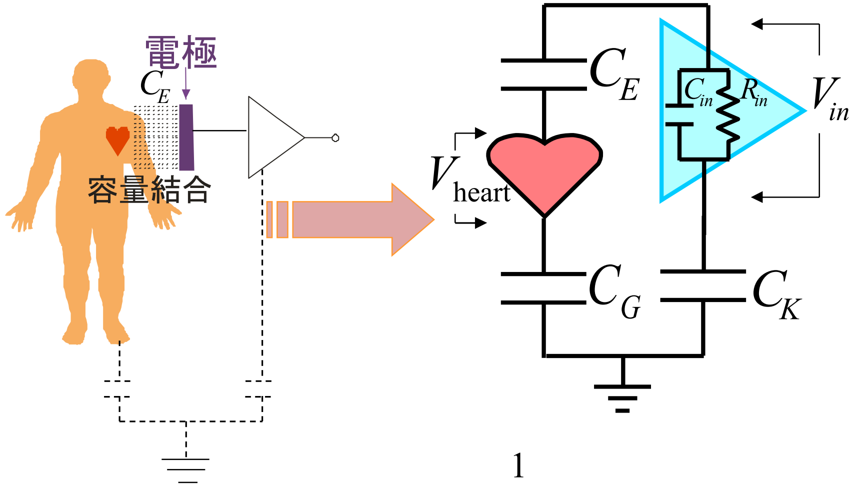
Smart Wear Soft Electrodes





Smart Wear Soft Electrodes

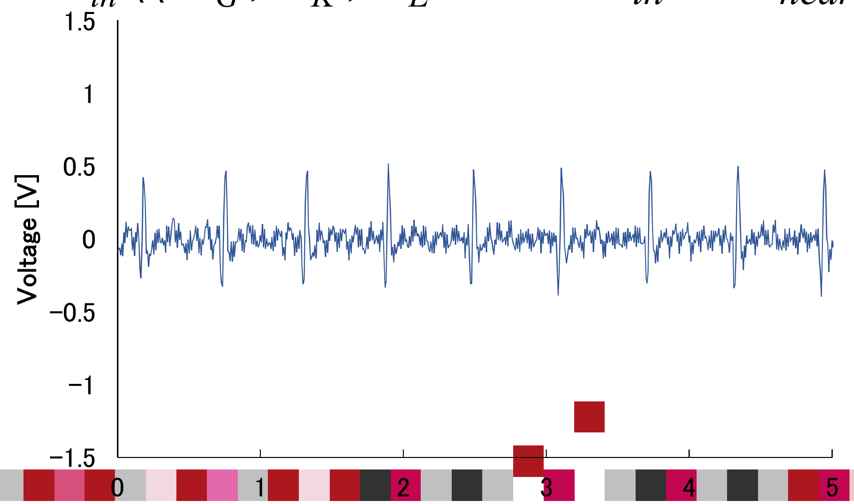
capacitive type electrode



$$\frac{V_{in}}{V_{heart}} = \frac{1}{\frac{1}{j\omega C_E R_{in}} + \frac{C_{in}}{C_E} + \frac{1}{j\omega C_G R_{in}} + \frac{C_{in}}{C_G} + \frac{1}{j\omega C_K R_{in}} + \frac{C_{in}}{C_K} + 1}$$

From the characteristics of the operational amplifier R_{in}

$$C_{in} \langle\langle C_G, C_K, C_E \qquad V_{in} \cong V_{heart}$$



Smart Wear Soft Electrodes

Wearable Device for Simultaneous Monitoring of ECG and Thoracic Impedance, including Respiratory

3.Undergraduate School of Science and Enginnering, Ritsumeikan University, Shiga, Japan

Introduction

- In previous study, we developed the wearable device for ECG measurement. -Fig.1
- Especially thoracic impedance includes important cardiorespiratory parameters, such as cardiac output, respiration rate, and amount of ventilation.

However…

A lot of information cannot be obtained without many sensor in the conventional method.

The purpose of this study was to develop a wearable device for simultaneous monitoring ECG and impedance including respiratory information using two dry electrodes.

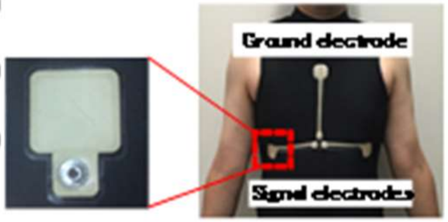


Fig.1 The wearable device for ECG

Method

Ⅰ. The ECG/Impedance measurement method – Fig.2

- The injection current frequency: 50kHz.
- The measured signals:
  ECG (10 – 100 Hz) , Impendance (884 - 100 kHz)

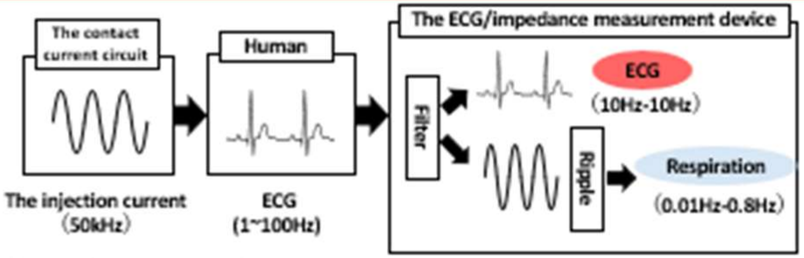


Fig.2 Impedance measurement method

Ⅱ. The electrode and base-wear (Bra-type) - Fig.3

- The electrode was made of the stretchable high conductive sheet (100 μΩ/cm).
- The position of electrodes was the CC5-lead.
- Stainless steel snappers were set for the connection between the electrodes and the developed device.

Fig.3 Bra-type

Ⅲ. Collection Method

- Subjects were the 10 healthy male (21.7±1.3year, 169.3±5.0cm, 60±6.6kg)
- Reference : Conventional biopotential measurement device (Polymate V) - ECG,
  LCR meter (IM3570) – Impendance, Oronasal airflow (TR-101A) - Respiration
- Respiration rate (RR) was controlled in 15 respiration cycle per minute(rcpm) and 30 rcpm by metronome.

Ⅳ. Signal processing (python ver3.6)

- Average RR interval(AVNN) : 1. Digital BPF (10-50 Hz) 2. Differential processing 3. Moving average 4. Peak detection
- Respiration interval : 1. Digital BPF (0.01-0.8 Hz) 2. Differential processing 3. Moving average 4. Peak detection

Wearable Device for Simultaneous Monitoring of ECG and Thoracic Impedance, including Respiratory

Result

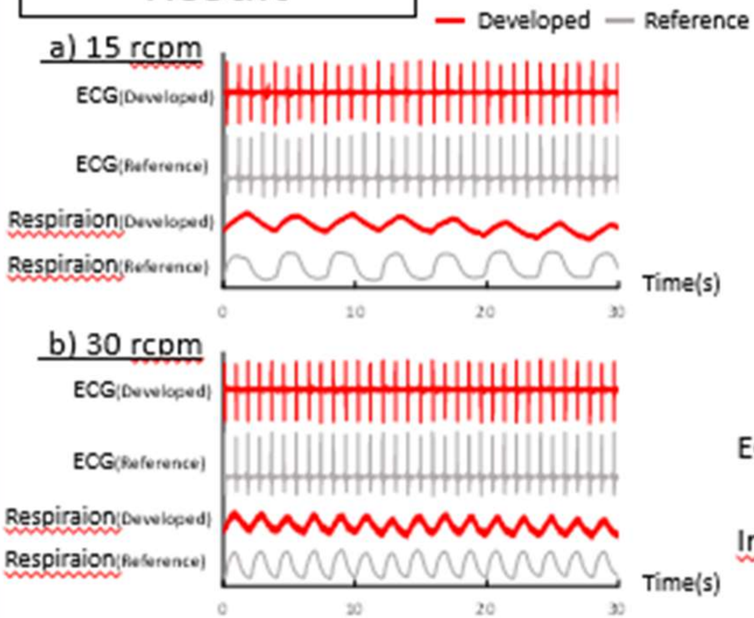


Fig.4 The raw data of two test: a) 15 rcpm and b) 30 rcpm
Red line: Developed device, Gray line: Reference

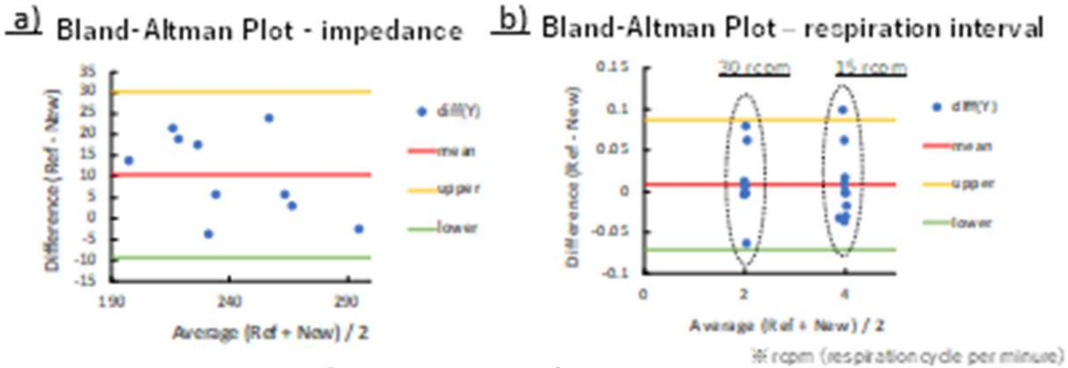


Fig.5 Bland-Altman Plot: a) Impedance and b) Respiration interval
Red line: Mean, Yellow line: Mean + 1.96SD, Green line: Mean – 1.96SD

ECG

- The R-peak and theRR were approximately same as both device. -Fig.4

Impendance

- The Impedance of both device also approximately coincide. -Fig.5 a)
- The mean of absolute respiratory interval errors between both measurements were 0.01 seconds of two tests. -Fig.5 b)

Conclusion

The result of this research shows that the developed device can measure heart rate and thoracic impedance including respiratory rate simultaneously.

Contactless Measurement

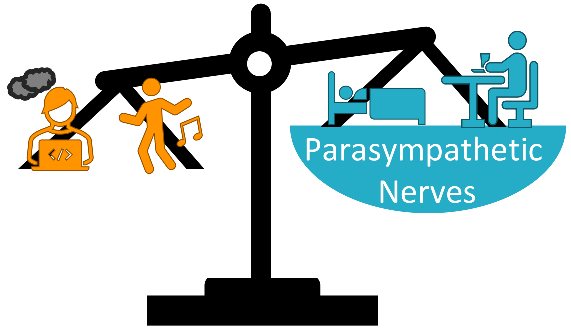
① Camera : Take a video of the face

▶ Calculate **Fasial** G/B ratio

TAWARON
TAWARON-HDC1

Resolution 1080 × 1920 [pix]
Frame Rate 30 [fps]

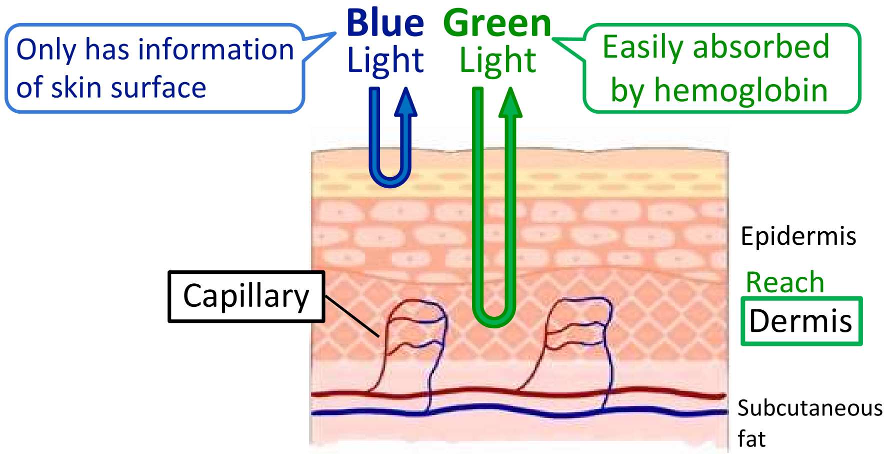
Autonomic Nervous System



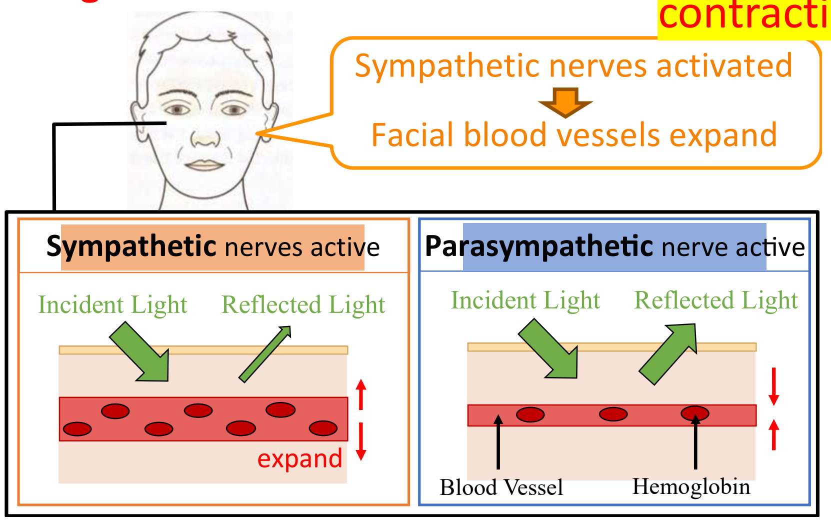
- Reflected Green light has information of hemoglobin
- Facial blood vessels change depending on the ANS
- Contraction and expansion of blood vessels changes the amount of hemoglobin

➢ Sympathetic nerves activate ⟹ Reflected Green light decreases

expansion
contraction



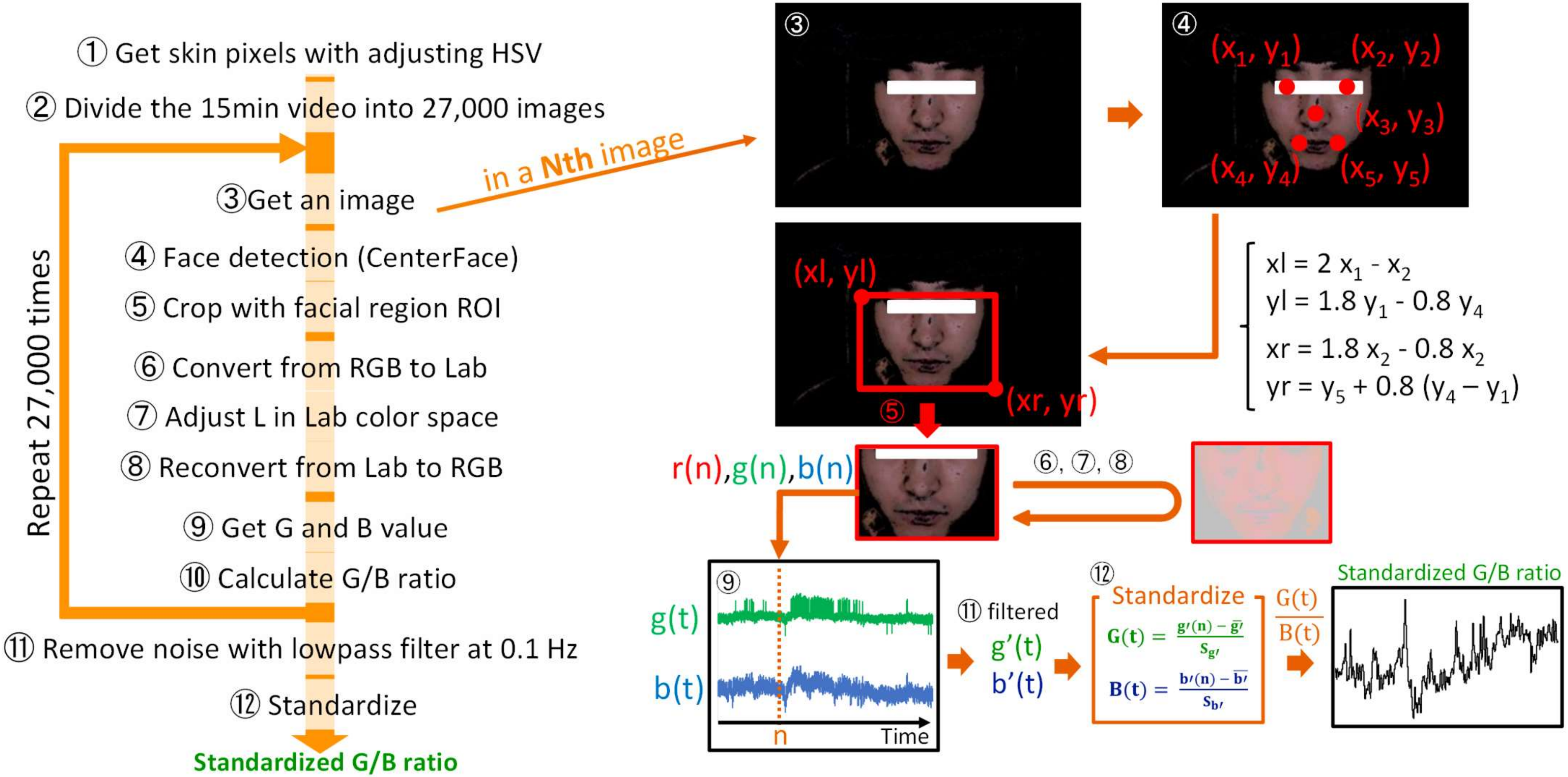
Structure in the skin



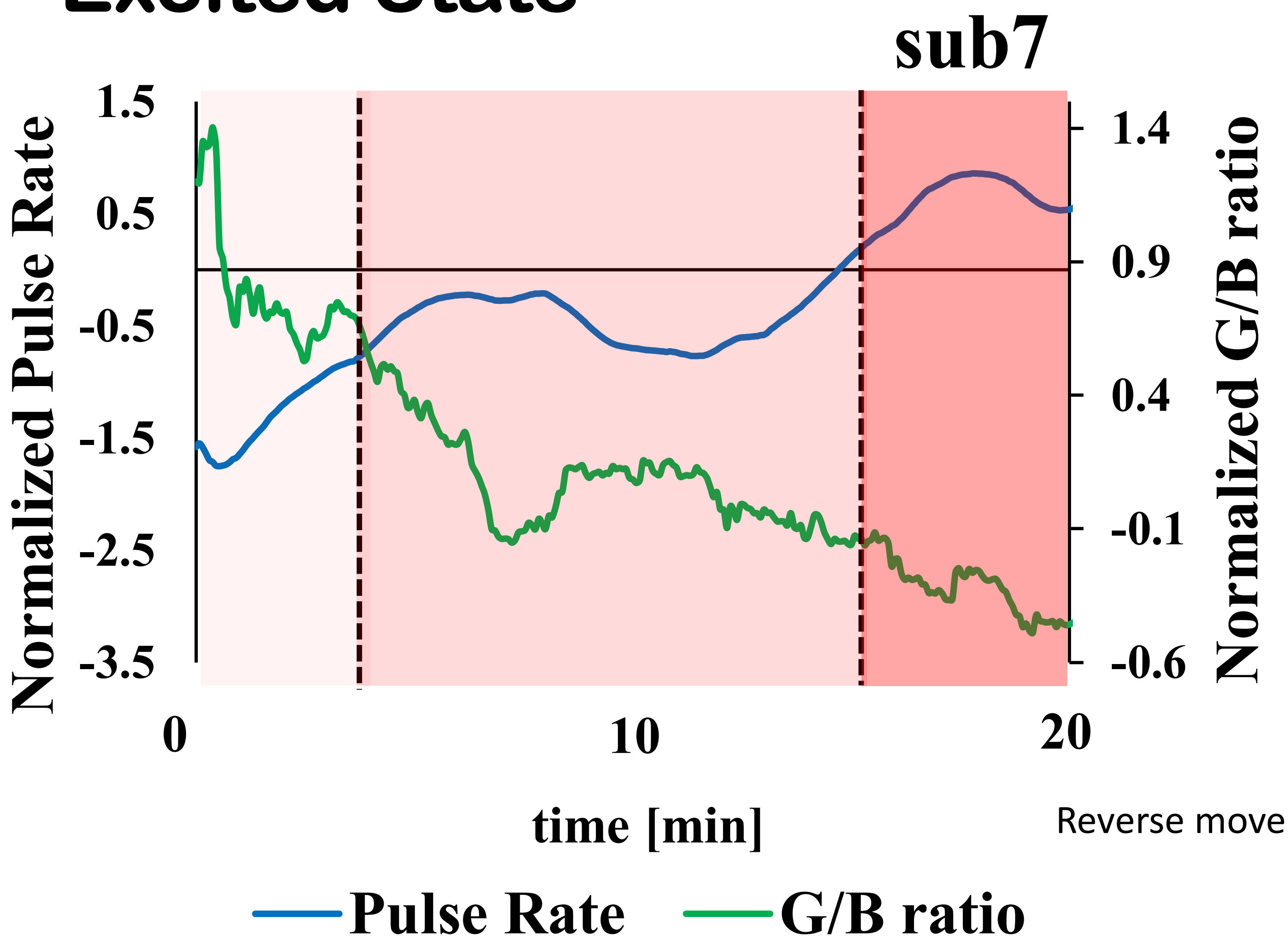
In this study

Measuring ANS using G/B ratio $\left(\frac{\text{Green value (has information of hemoglobin and skin surface)}}{\text{Blue value (only has information of skin surface)}}\right)$ **in facial RGB Images**

Contactless Measurement



Excited State



Reverse movement.

Smart Wear Soft Electrodes

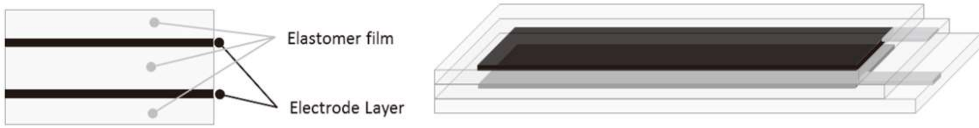
Q4: What are the advantages of using soft electrodes? Please imagine a scene of interaction with the robot.

What kind of control signals can we use the physiological quantities acquired from soft electrodes as control signals to the robot?

Table of Contents for Today's Lecture

Sensor (Elasticity Strain Sensor C-STRETCH®)

Manufactured by Bando Chemical Co., Ltd. elastic strain sensor C-STRETCH®

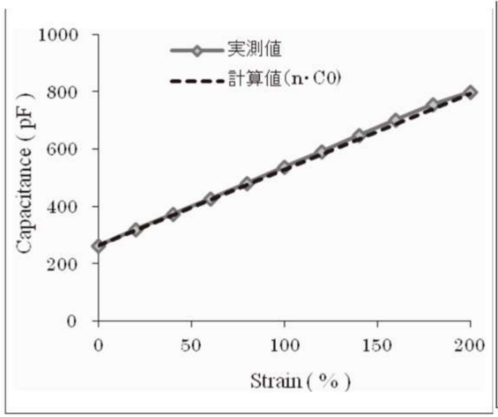


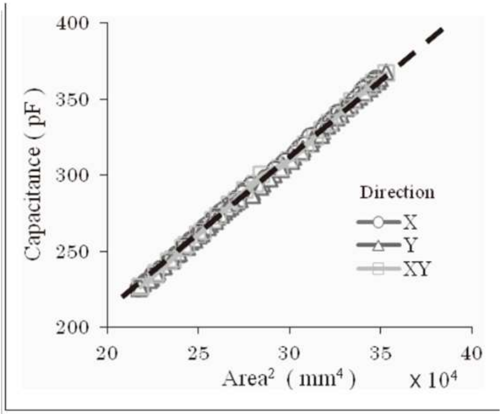
Schematic diagram of the structure (left: cross-sectional view, right: perspective view)[3]

$$C\ (capacitance) = \varepsilon\ (S(area))/(D(distance))$$

$$C = KS^2\ (K \text{ is a constant})$$

Capacitance changes due to sensor elongation (change in area)
→ (can be converted to a voltage value by a dedicated transmitter)





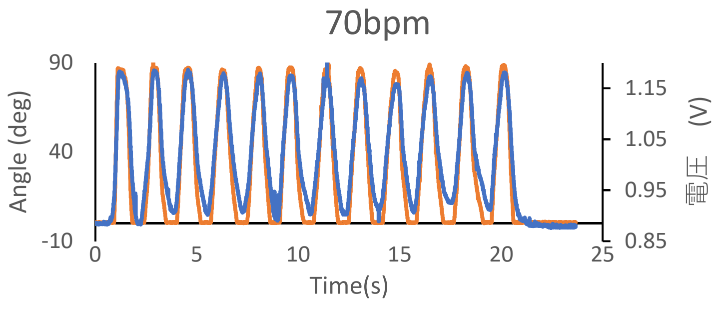
Relationship between detection area and capacitance and comparison of elongation directions[3]

Relationship between single-axis elongation rate and capacitance [3]

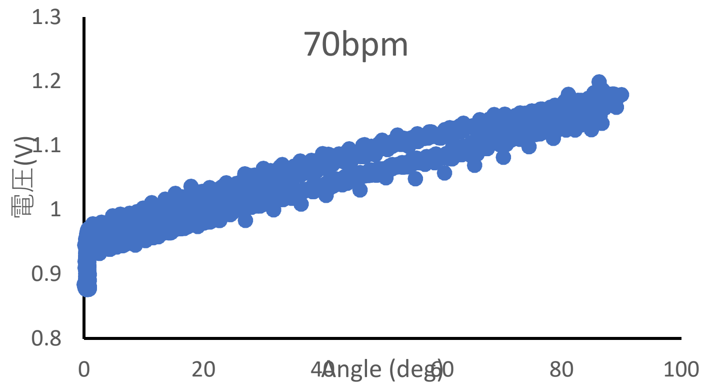
Features of the sensor
- **Low hysteresis**
- **Thin, flexible and expandable**
- **When attached to a curved surface such as the human body**

Excellent movement tracking
- **Ability to detect exercise, etc. with high repeatability[3]**

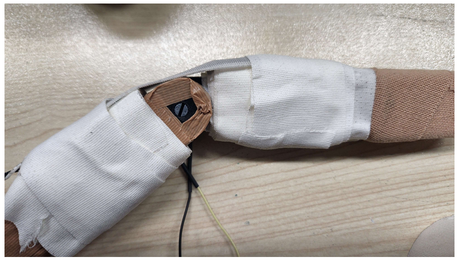
Results of angular displacement



Comparison of angular displacement and displacement of voltage value applied to the sensor (70 bpm)



Correspondence between angular displacement and voltage value applied to the sensor (70 bpm)



Angle meter and telescopic strain sensor when the angle is changed (left), 0 degrees (center), 45 degrees (right), 90 degrees

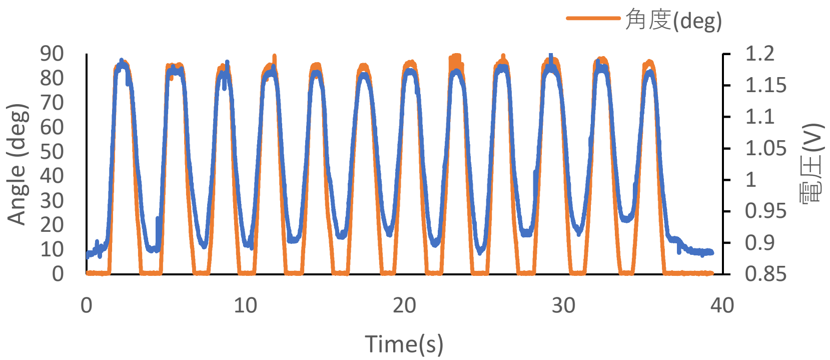
・Linear relationship between angle and sensor value

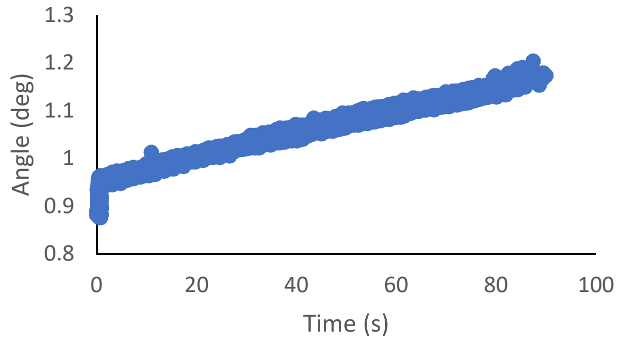
Since it is not in close contact with the joint, the sensor is deflected when the bend is shallow.

Results of angular displacement

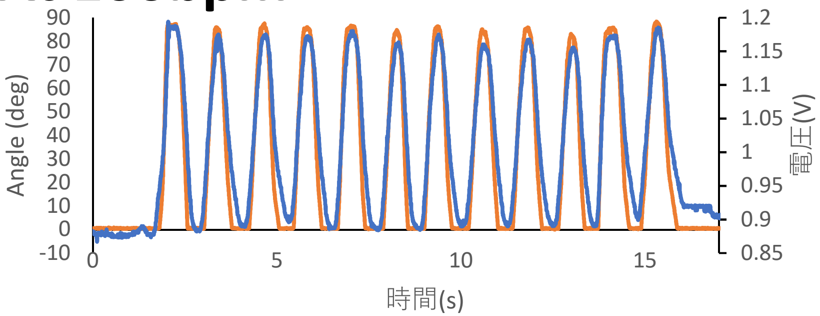
Followability for deformation speed

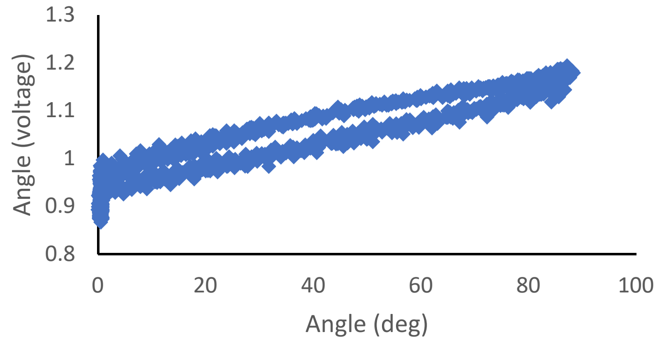
At 40bpm





At 100bpm





When moving quickly, the response of the sensor is delayed in bending and stretching. **Not fully returning to its original form.**

Conductive supporter fabricated

- Supporter composed of conductive fibers in part

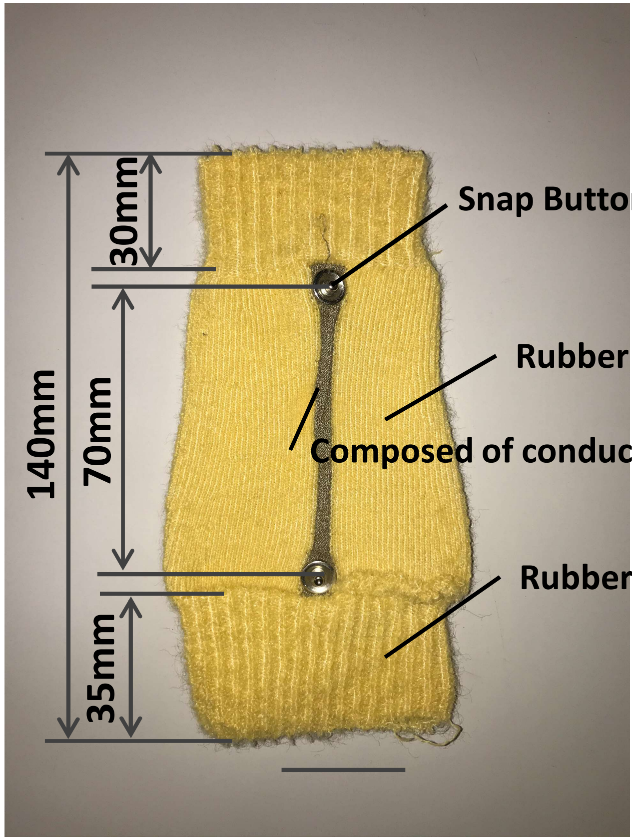
✓ <u>When the supporter is manufactured, part of it is composed of conductive fibers.</u>

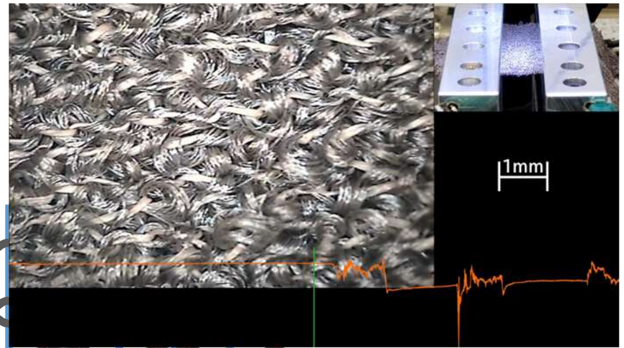
✓ <u>Initial resistance: Approx. 25 Ω</u>

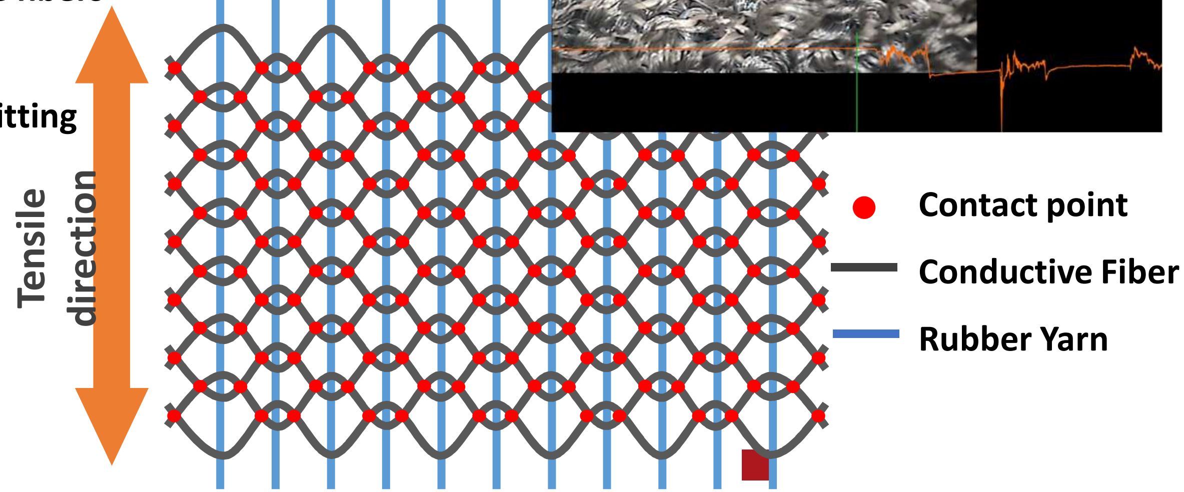
✓ <u>Number of contact points between conductive threads: Many</u>

✓ <u>Weft: Conductive yarn</u>

✓ <u>Warp: Rubber thread</u>







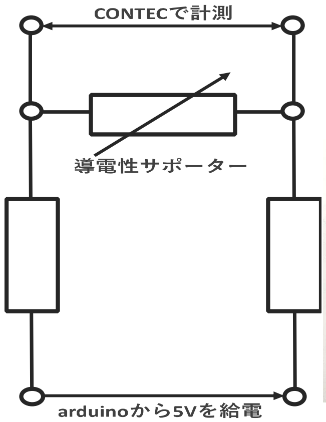
Conductive supporter fabricated

Measure the difference in flexion speed

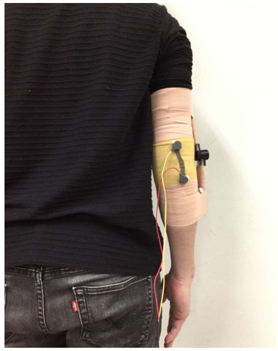
Simultaneous measurement of supporter and elbow angle

Sampling frequency: 100Hz

Equipment used: CONTEC (AD converter)



side



back

□ Experiment 1

16 seconds total: 1 set × 10 sets

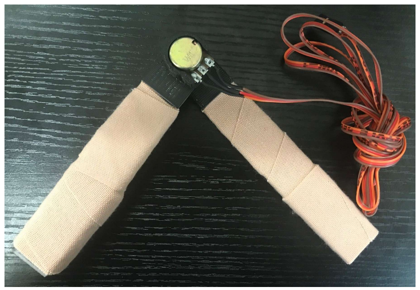
4sec	4sec	4sec	4秒
Standby in extension state	Slow flexion	Wait in a bent state	Slow extension

□Experiment2

Sum 8sec/1set × 10set

2 sec	2 sec	2 sec	2 sec
Slow extension	Slow flexion	Wait in a bent state	Slow extension

potentiometer B10K



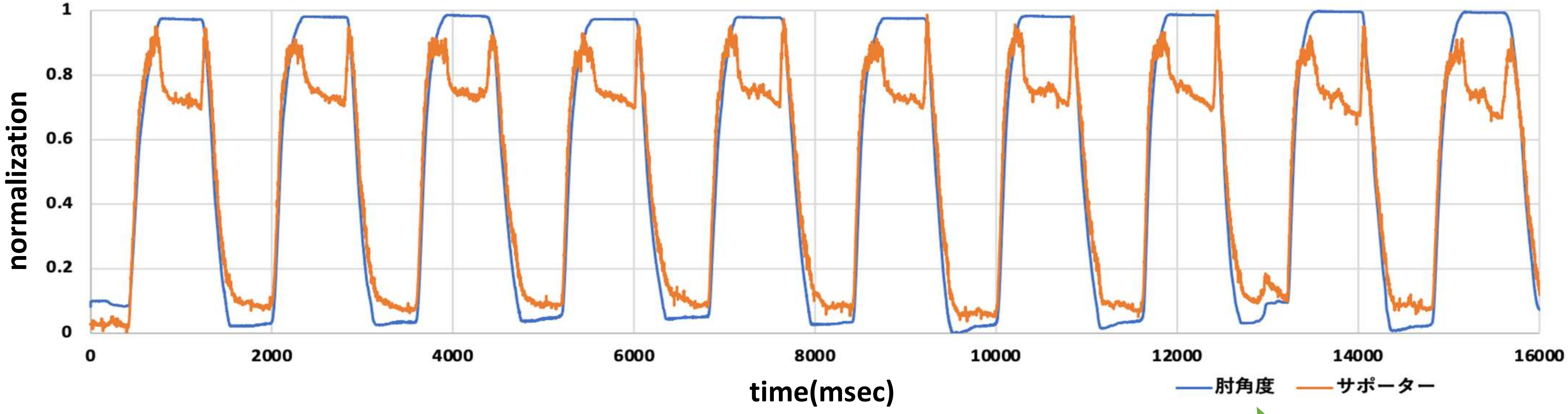
Joint angle measuring instrument using B10K

Futurize. きみの意志が、未来。

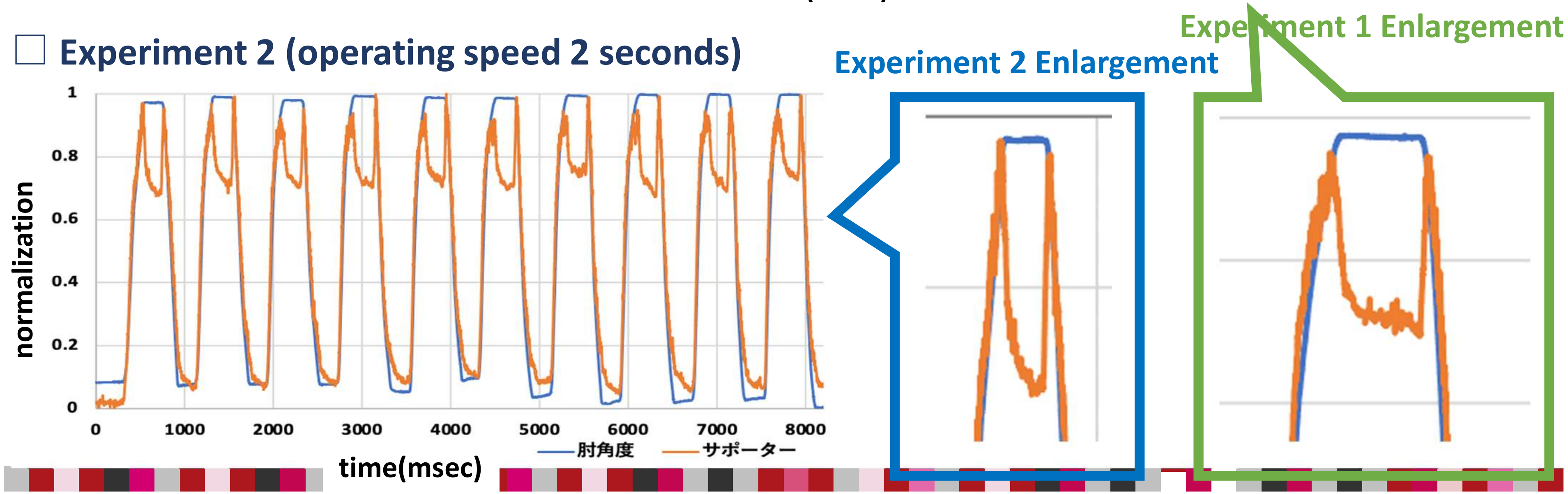
Characteristic confirmation experimental results

Supporter partially composed of conductive yarn

- Experiment 1 (operating speed 4 seconds)



- Experiment 2 (operating speed 2 seconds)



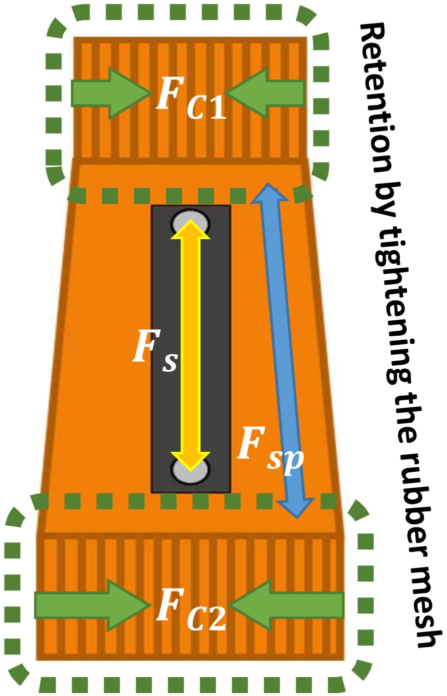
Characteristic confirmation experimental results

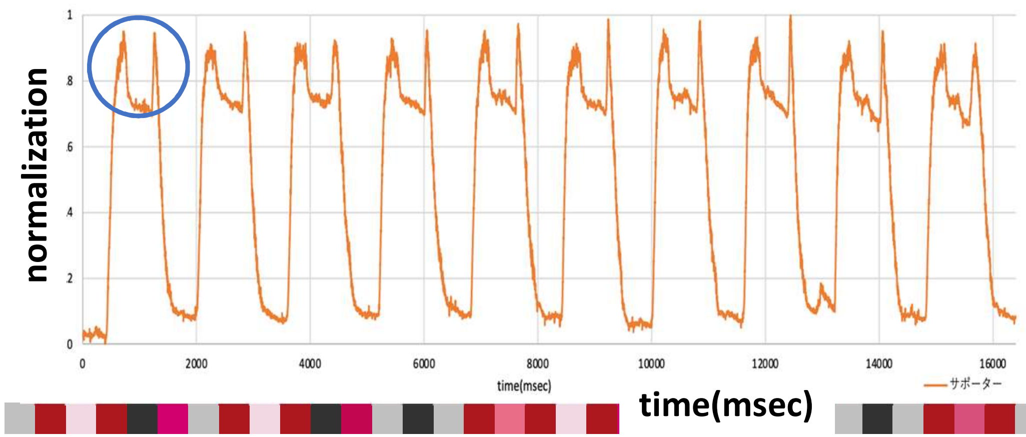
Experiment 4 (Investigating the cause of resistance reduction during flexion stop)

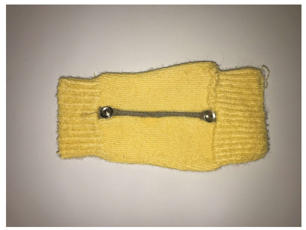
Hypothesis

1. During bending, the resistance value increases due to the stretching of the sensing part composed of conductive threads
2. When bending is stopped, the elastic force works and the supporter tries to return to its original state, so the resistance value decreases (blue circle)
   * The friction force caused by the rubber mesh in the green frame does not withstand the elastic force that contracts the supporter.
3. When the extension is started, the resistance value rises rapidly due to the greater elastic force

$$F_{C1} + F_{c2} < F_s + F_{sp} \qquad F_s > F_{sp}$$







F_{sp}: *Resilience of supporters*

F_s: *Elastic force of the sensing section*

F_C2, F_C2: Tightening force by rubber mesh

Characteristic confirmation experimental results

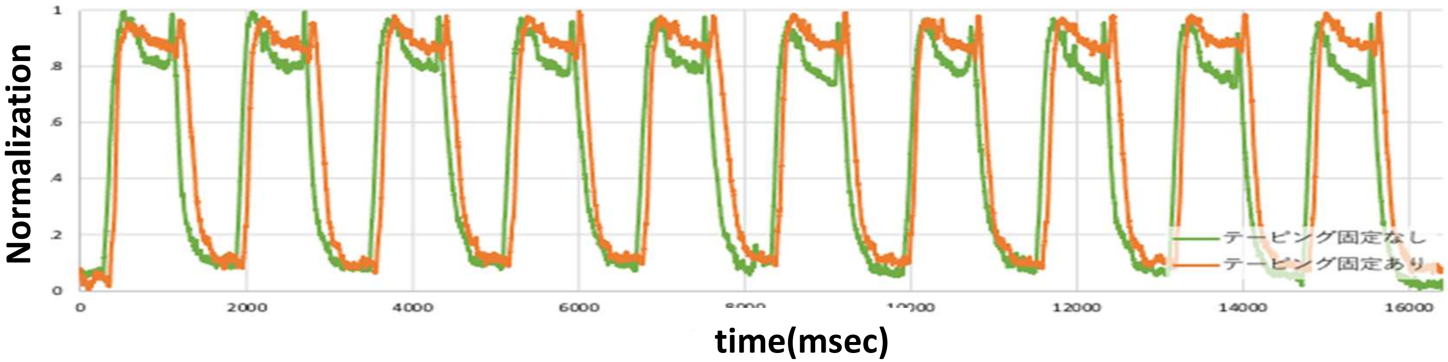
□ Experiment 4 (Investigating the cause of resistance reduction during flexion stop)

Experimental

- ✓ Non-elastic taping on the top and bottom edges of the supporter to prevent misalignment
- ✓ Measured only by supporters
- ✓ Conducted two experiments, one with and one without taping
- ✓ The experimental protocol is the same as in Experiment 1.

Non-elastic taping (NICHIBAN)
https://www.nichiban.co.jp/general/health/

Investigation of the Factors Contributing to the Decrease in Resistance During Flexion Stop)



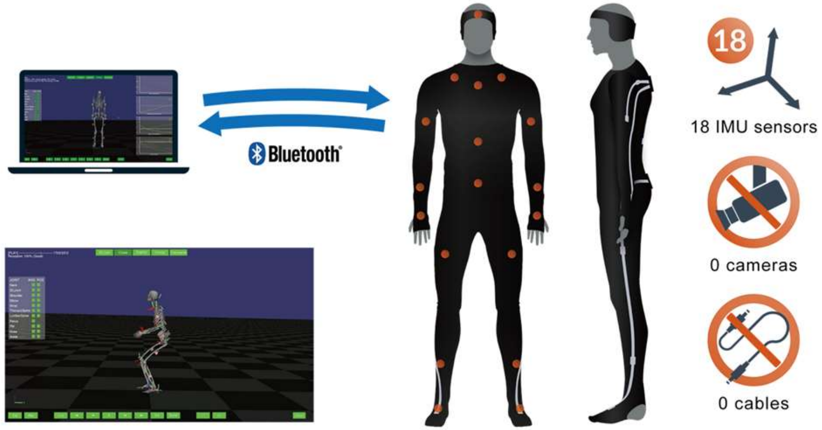
Difficulty of attachment for human joint

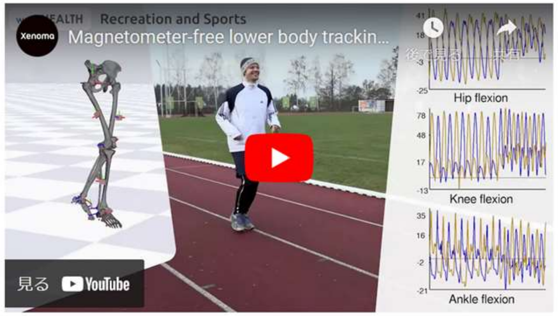
When fixed with taping, the decrease in resistance during flexion was suppressed.

Elastic sensor application

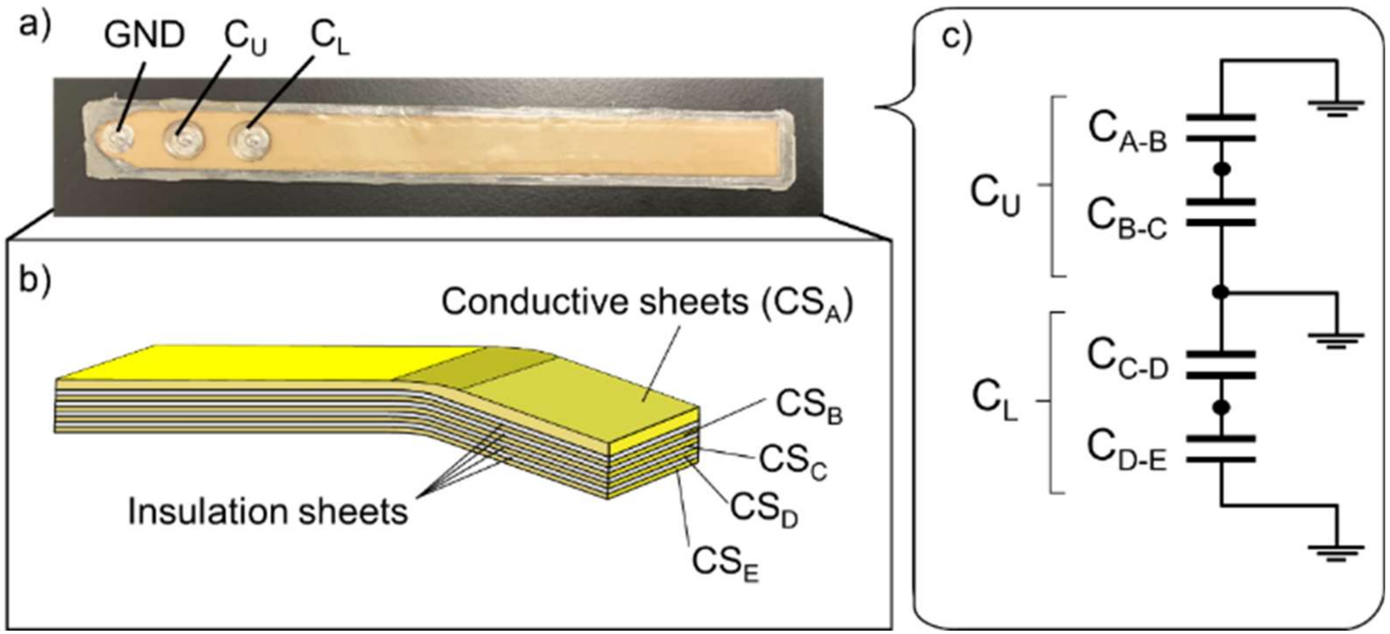
https://www.youtube.com/watch?v=MIjISflodZk

https://www.youtube.com/watch?v=z6S8XiKcFWk



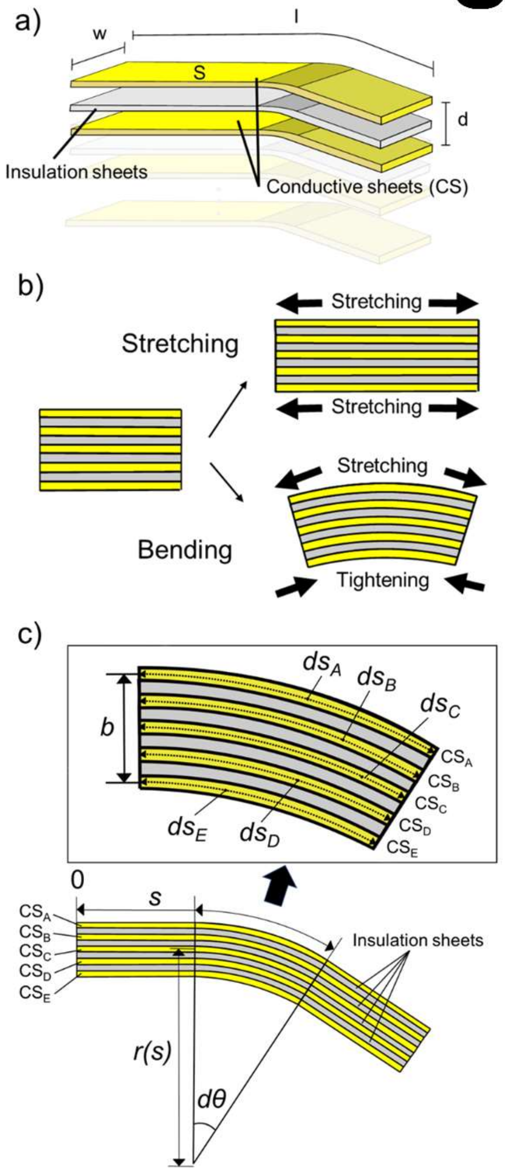


Bending Sensor



D. Goto, Y. Sakaue, T. Kobayashi, K. Kawamura, S. Okada and N. Shiozawa, "Bending Angle Sensor Based on Double-Layer Capacitance Suitable for Human Joint," in IEEE Open Journal of Engineering in Medicine and Biology, vol. 4, pp. 129-140, 2023, doi: 10.1109/OJEMB.2023.3289318.

Bending Sensor



$$\begin{cases} ds_A = \left(r(s) + \frac{b}{2}\right) \cdot d\theta \\ ds_B = \left(r(s) + \frac{b}{4}\right) \cdot d\theta \\ ds_C = r(s) \cdot d\theta \\ ds_D = \left(r(s) - \frac{b}{4}\right) \cdot d\theta \\ ds_E = \left(r(s) - \frac{b}{2}\right) \cdot d\theta \end{cases}$$

$$\begin{cases} \varepsilon_A = \frac{ds_A - ds_C}{ds_c} = \frac{b}{2r(s)} \\ \varepsilon_B = \frac{ds_B - ds_C}{ds_c} = \frac{b}{4r(s)} \\ \varepsilon_D = \frac{ds_D - ds_C}{ds_c} = -\frac{b}{4r(s)} \\ \varepsilon_E = \frac{ds_E - ds_C}{ds_c} = -\frac{b}{2r(s)} \end{cases}$$

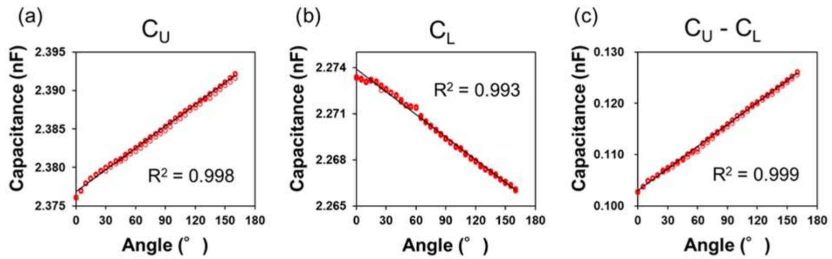
$$\begin{cases} \Delta l_A = \int_0^l \varepsilon_A ds = \int_0^\theta \frac{b}{2r(s)} r(s) d\theta = \left[\frac{b}{2}\theta\right]_0^\theta = \frac{b}{2}\theta - 0 = \frac{b}{2}\theta \\ \Delta l_B = \int_0^l \varepsilon_B ds = \int_0^\theta \frac{b}{4r(s)} r(s) d\theta = \left[\frac{b}{4}\theta\right]_0^\theta = \frac{b}{4}\theta + 0 = \frac{b}{4}\theta \\ \Delta l_D = \int_0^l \varepsilon_D ds = \int_0^\theta -\frac{b}{4r(s)} r(s) d\theta = \left[-\frac{b}{4}\theta\right]_0^\theta = -\frac{b}{4}\theta + 0 = -\frac{b}{4}\theta \\ \Delta l_E = \int_0^l \varepsilon_E ds = \int_0^\theta -\frac{b}{2r(s)} r(s) d\theta = \left[-\frac{b}{2}\theta\right]_0^\theta = -\frac{b}{2}\theta + 0 = -\frac{b}{2}\theta \end{cases}$$

$$\Delta C = (C_{A-B} + C_{B-C}) - (C_{C-D} + C_{D-E})$$

$$= \left\{ \varepsilon_0 \varepsilon_r \frac{w(l + \Delta l_A)}{\frac{b}{4}} + \varepsilon_0 \varepsilon_r \frac{w(l + \Delta l_B)}{\frac{b}{4}} \right\}$$

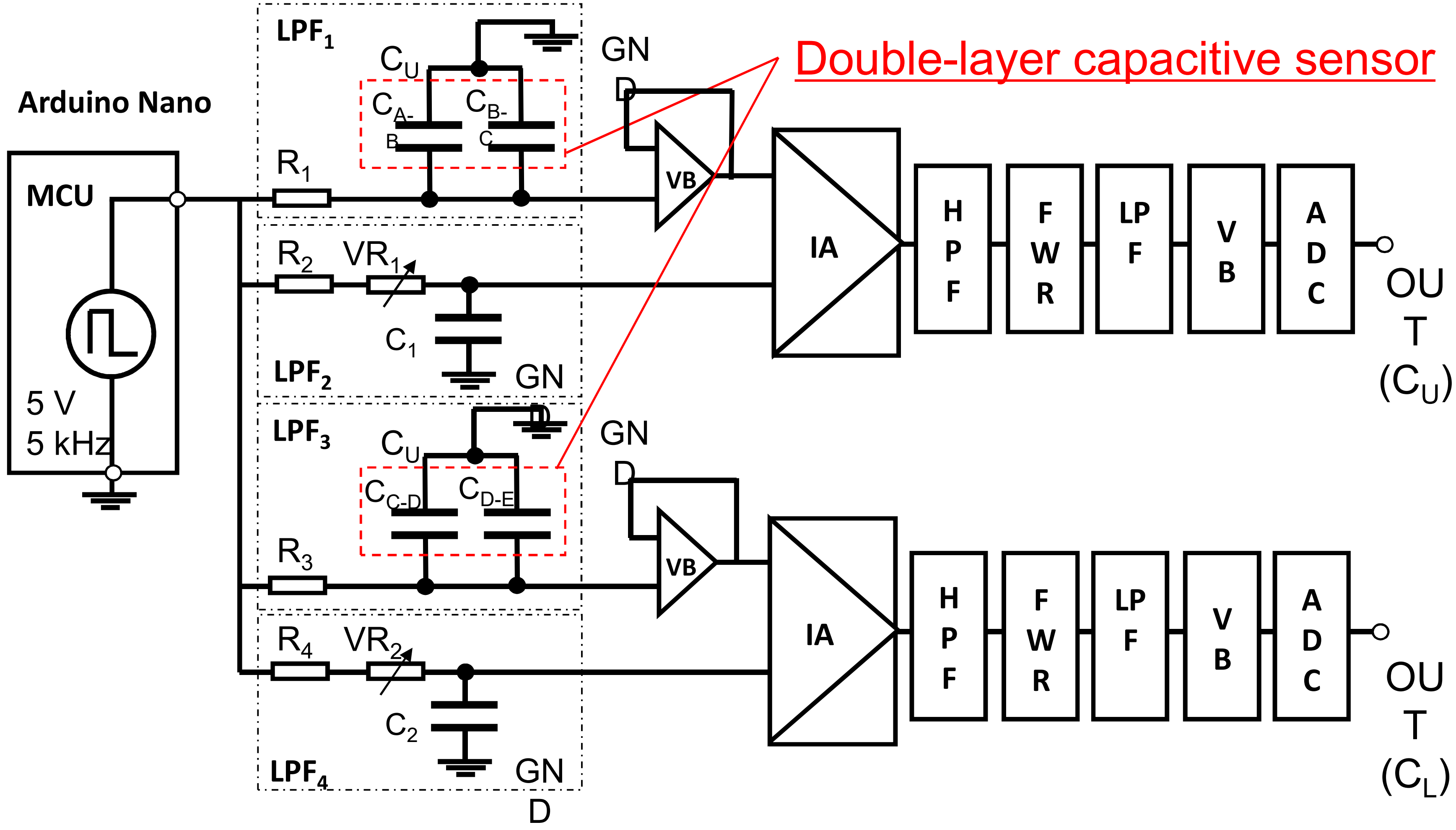
$$- \left\{ \varepsilon_0 \varepsilon_r \frac{w(l + \Delta l_D)}{\frac{b}{4}} + \varepsilon_0 \varepsilon_r \frac{w(l + \Delta l_E)}{\frac{b}{4}} \right\}$$

$$\Delta C = 2\varepsilon_0 \varepsilon_r w\theta$$

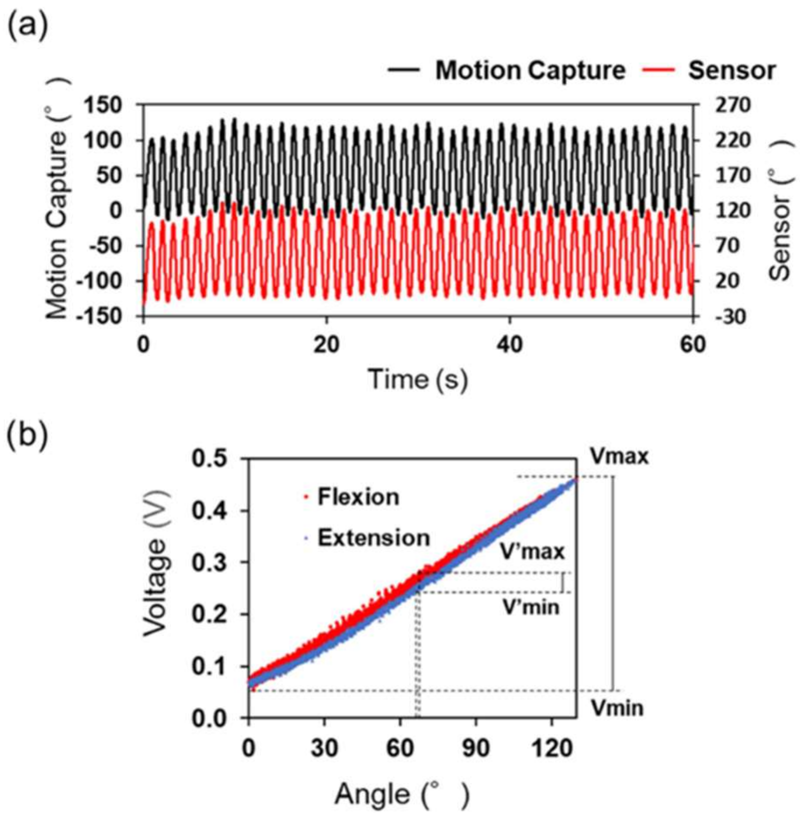


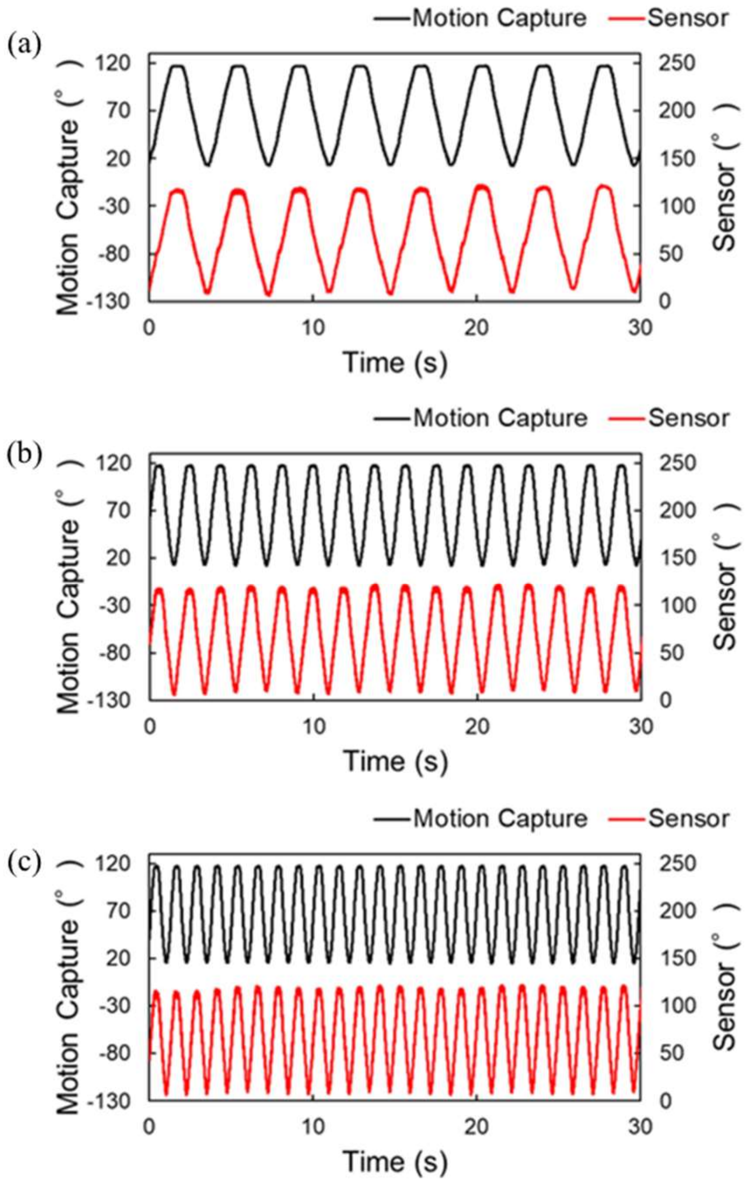
Correlation plots between the capacitances ((a) CU, (b) CL, and (c) CU–CL) measured by the chemical impedance analyzer and the
bending angle measured by the goniometer.
CU–CL was calculated by subtracting CU from CL

Circuit Design



Bending Sensor

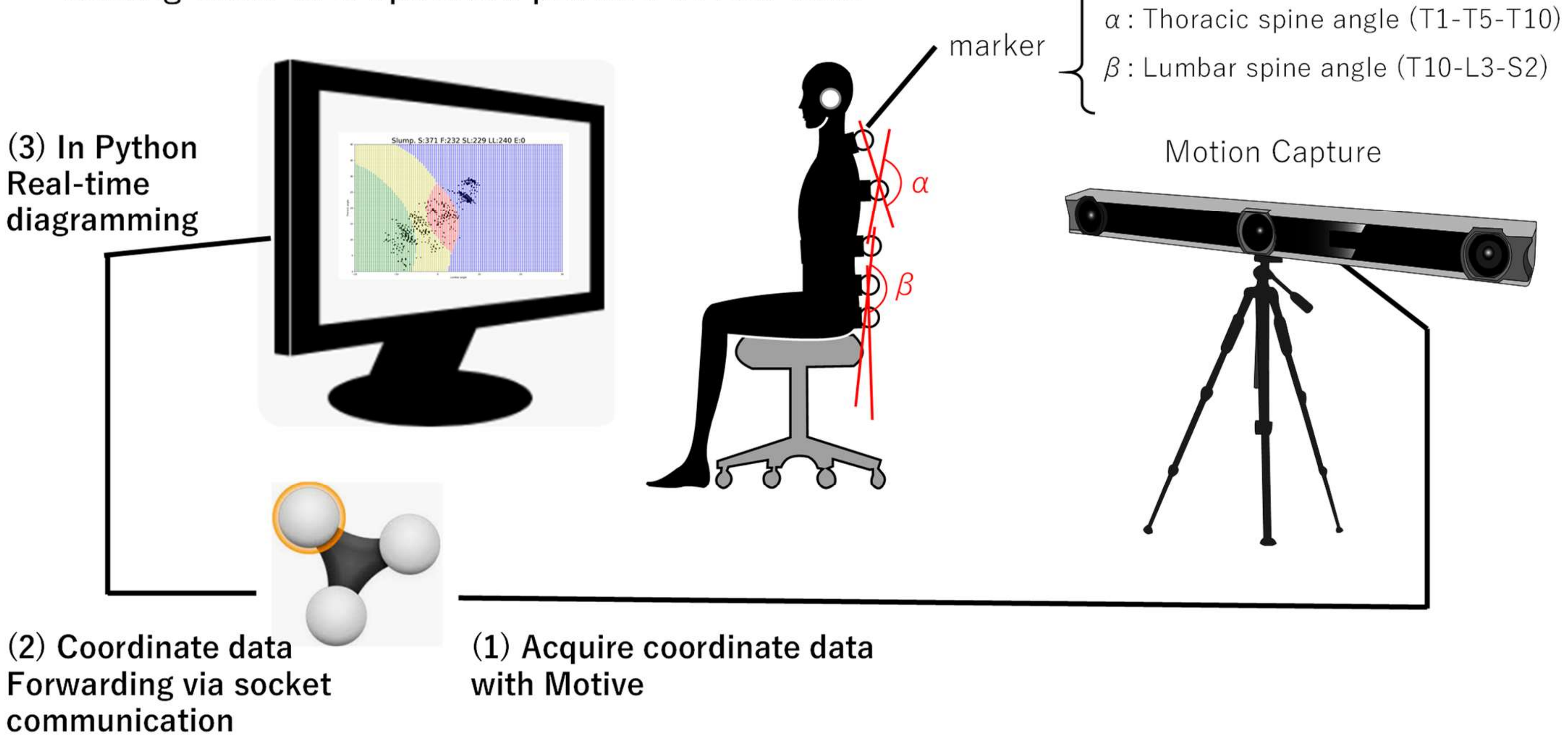




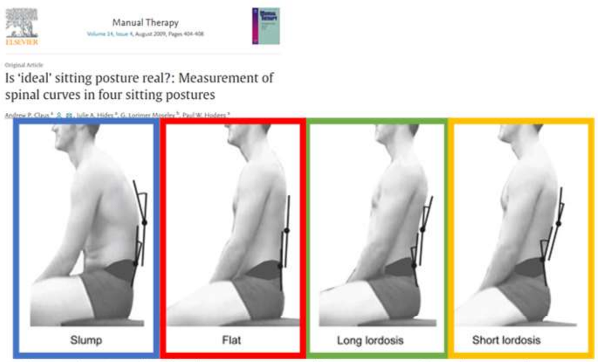
(a) 16 rpm, (b) 32 rpm, and (c) 48 rpm

Human Posture Sensing

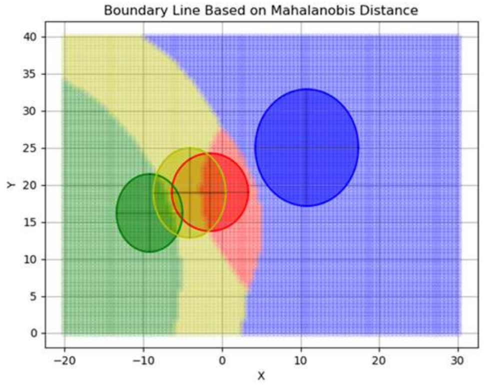
- Guiding them to a specified posture in real time

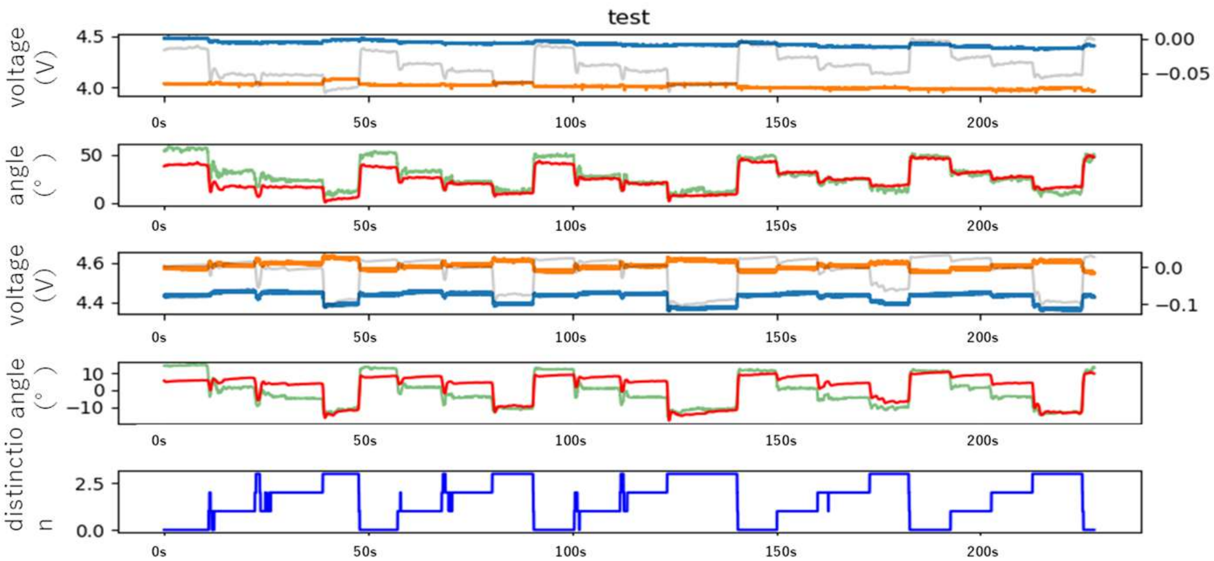


Human Posture classification



Claus, Andrew P et al. "Is 'ideal' sitting posture real? Measurement of spinal curves in four sitting postures." *Manual therapy* vol. 14,4 (2009): 404-8. doi:10.1016/j.math.2008.06.001





Futures: Sensor 1(Estimated Angle), Sensor 2 (Estimated Angle),

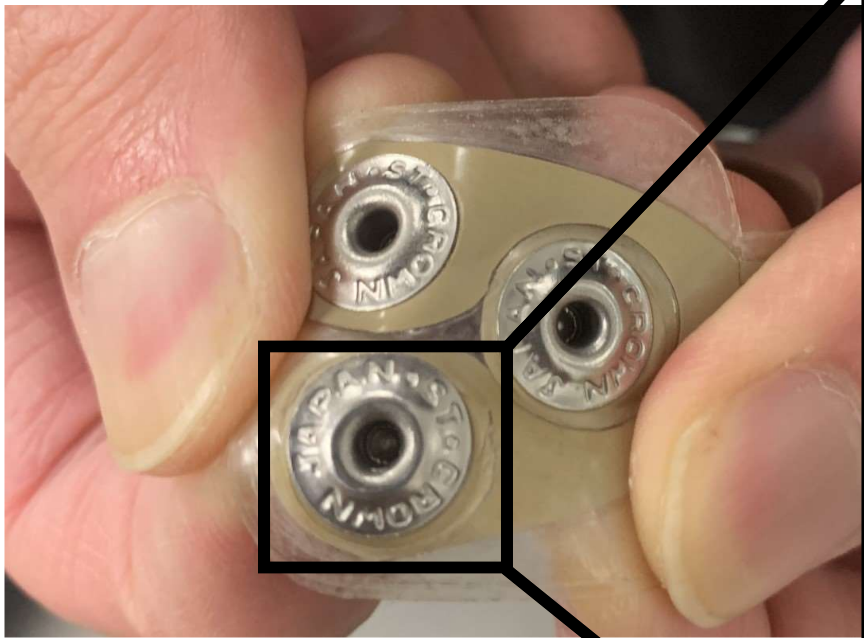
Model: Logistic Regression
acc: 0.972
precision: 0.904 1. 1. 1.
recall: 1. 0.868 1. 1.
f1-score: 0.95 0.929 1. 1.

Model: Decision Tree
acc: 0.947
precision: 1. 1. 0.833 1.
recall: 0.8 1. 1. 1.
f1-score: 0.889 1. 0.909 1.

Model: SVM
acc: 0.980
precision: 0.943 0.979 1. 1.
recall: 1. 0.924 0.984 1.
f1-score: 0.97 0.951 0.992 1.

May have some probrems

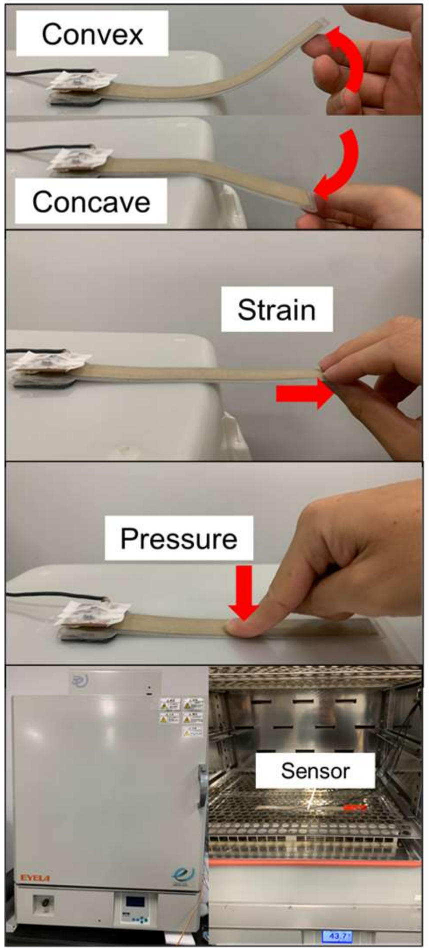
Conductive, Strechable sensor

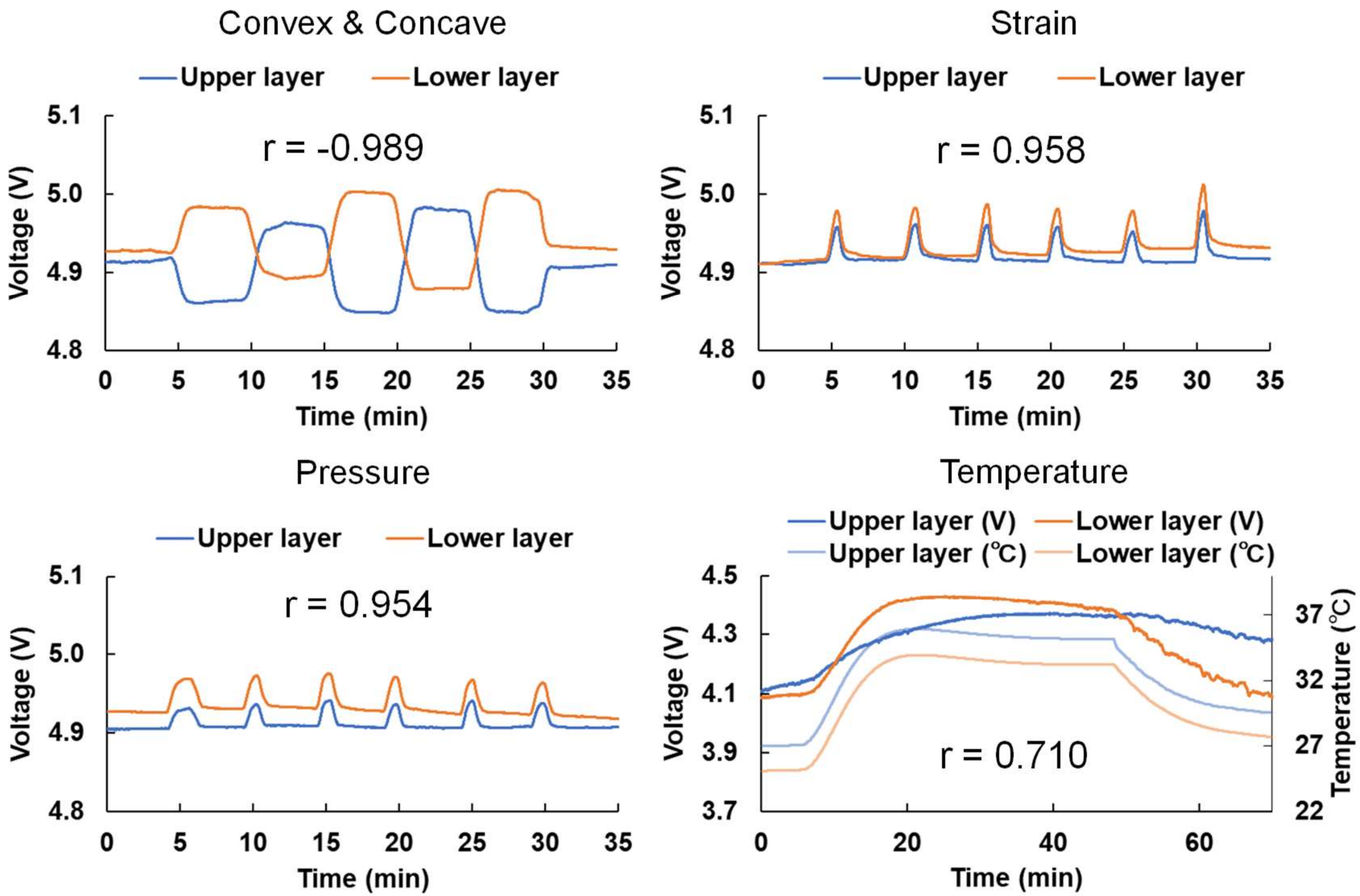


Repeated Use,,,,
Taking a load,,,,

May have some probrems

Capacitance type sensor





Changing Temperature, Humidity,,,,

Smart Wear Soft Electrodes

Q5: Let's think about soft sensors for human motion measurement.

Principles, advantages, and disadvantages of extension sensors.

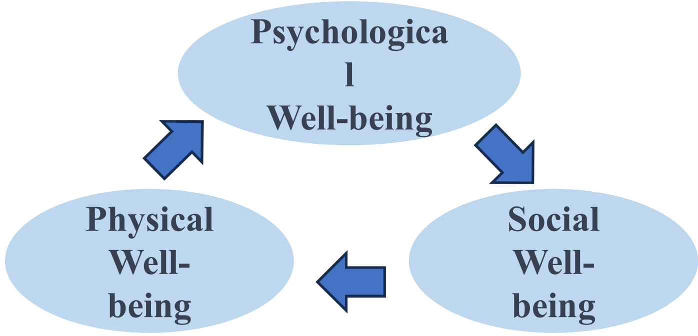
Principles, advantages, and disadvantages of bending sensors.

Which sensor is better for robotic applications? Give an example and explain.

Table of Contents for Today's Lecture

Soft Robotics Actuator for Human

Sustainable Health Management for Well-being



Physical Well-being:
Healthy body, Good physical fitness, Proper nutrition, Periodic exercise…etc

Psychological Well-being:
Self-fulfillment, The utilization of stress reduction techniques, Appropriate handling of psychological challenges…etc

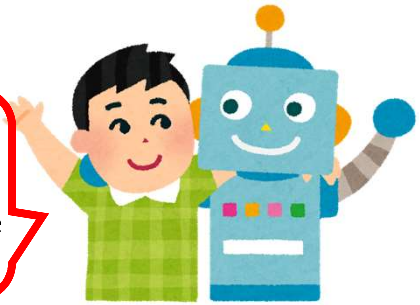
Social Well-being:
Healthy interpersonal relationships, Social connections, communication skills, Empathy, Cooperation, Leadership…etc

Sustainable Health Management approach

To achieve these in a comprehensive manner…

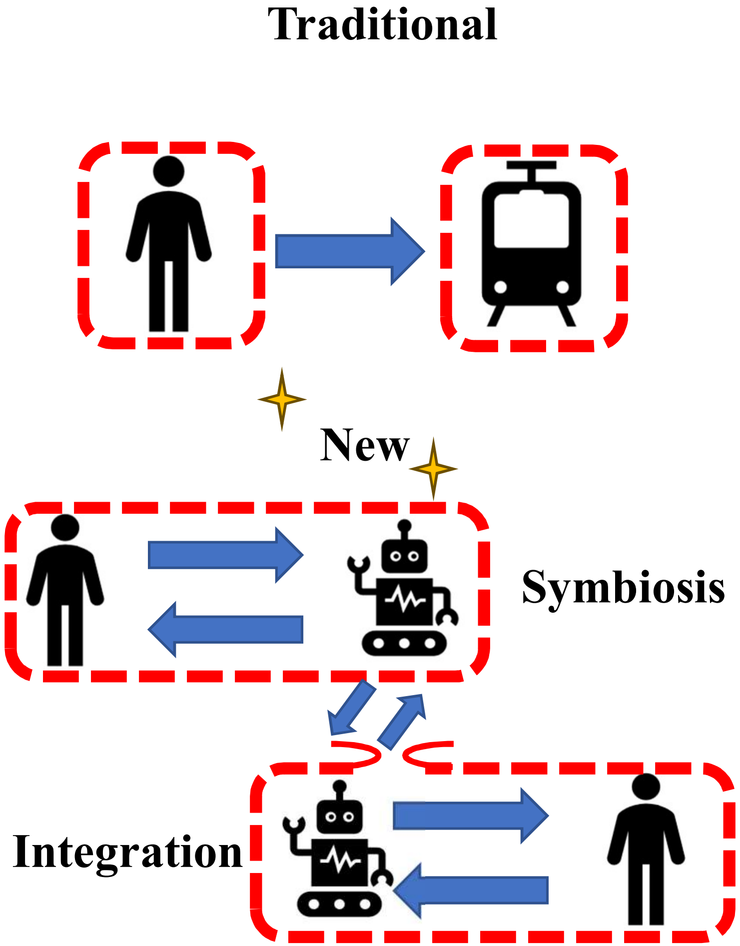
focused

Routine machine Intervention with people



Achieved	Health management through routine biometric measurements
Not now	Integrating humans and machines to improve health

A New Man-Machine Relationship



- Until now, people use machines.
  →Trains, a machine as a means of transportation
- Man and machine are independent as "individuals”

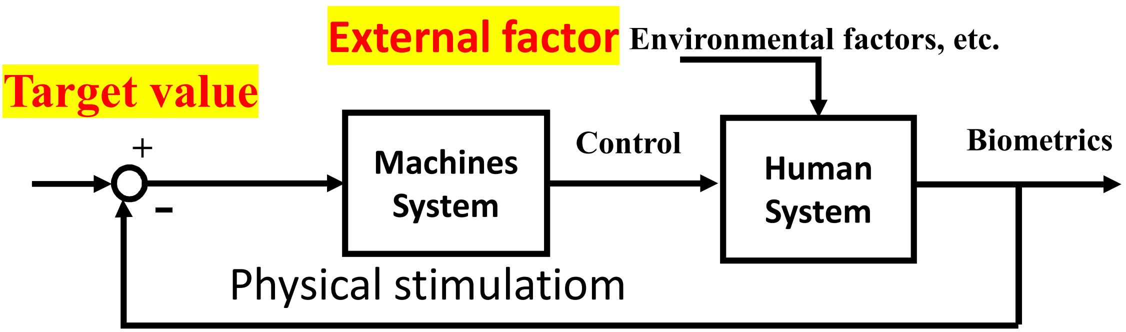
➡ ・Health management is possible,
but health promotion is not.
depends on individual efforts

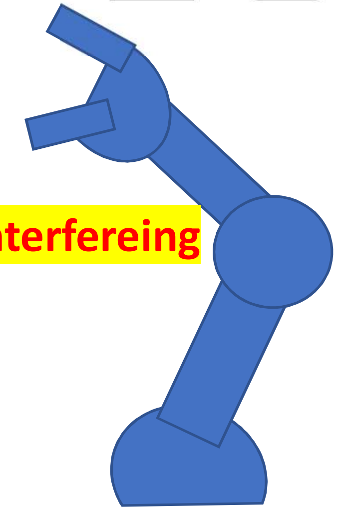
- Health management through routine biometric measurements is realized
- Integrating humans and machines to improve health

➡ **Control of the daily human condition**
By robotic tequniques

A New Man-Machine Relationship

Basic block diagram of the new man-machine





Biometrics

Defines the optimal human condition(**target value**), integrates with mechanical systems, and controls the condition of the human.

Interfereing

Two goals that need to be achieved

Human System

- Modeling the human body and determining target values
- Creating machine systems that can control human input

Machines System

Deformable Pillow

Background: 1 in 5 people in Japan are dissatisfied or have problems sleeping

Purpose: Rock the head through the respiratory cycle(Perrault et al., 2019)

Result: Facilitated sleep onset in 4 out of 6

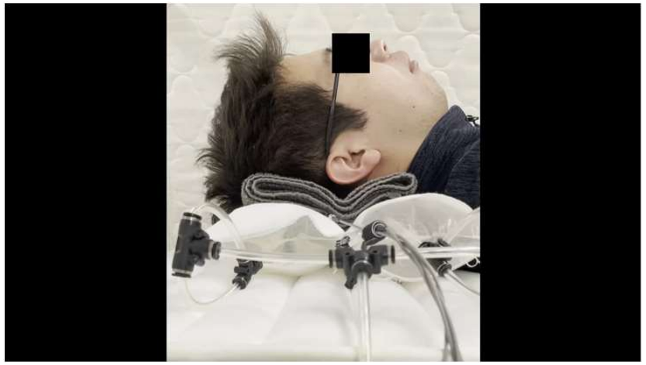


Fig. Deformable Pillow

Previous work :

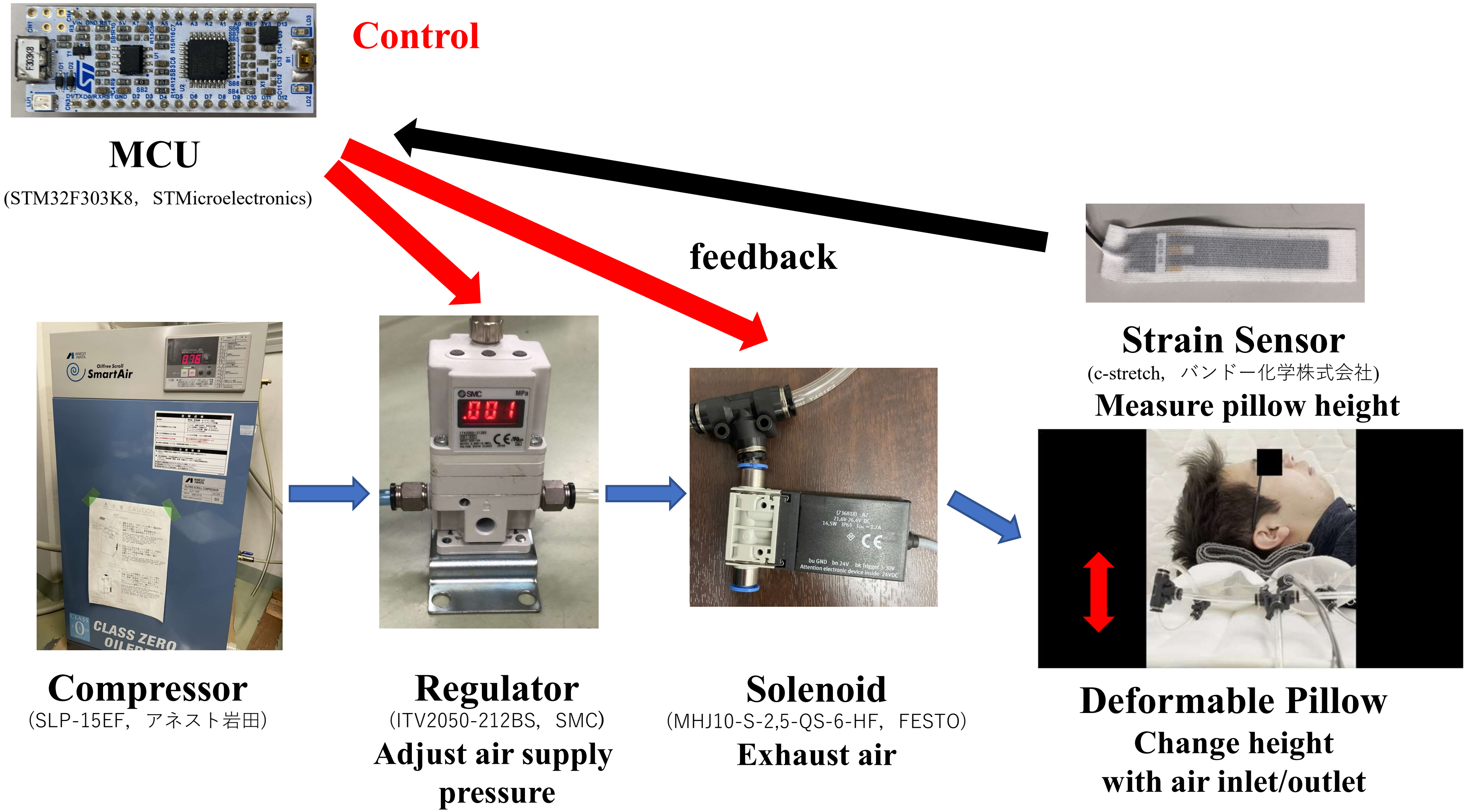
- Effect of inducing sleep by shaking the body of mice(Konstantinos, 2019)
- Synchronization of neural firing(Perraultら, 2019), Acclimation to constant stimuli(Öztürk-Çolakら, 2020)

Target Value

Tested the effect of "inducing sleep onset" by rocking the head with a pillow at a respiratory cycle of 0.25 Hz.

Konstantinos Kompotis's ,"Rocking Promotes Sleep in Mice through Rhythmic Stimulation of the Vestibular System,"Current Biology,Volume 29,Issue 3,4 February 2019.
A. A.Perrault, A. Khani, C. Quairiaux, K. Kompotis, P. Franken, M. Muhlethaler, S. Schwartz , L. Bayer, "Whole-Night Continuous Rocking Entrains Spontaneous Neural Oscillations with Benefits for Sleep and Memory," Current Biology, February 2019
A. Öztürk-Çolak, S. Inami, J. R.Buchler, P. D.McClanahan, A. Cruz, C. Fang-Yen , K. Koh, "Sleep Induction by Mechanosensory Stimulation in Drosophila," Cell Reports, 2020.

Deformable Pillow



Evaluation Method for Deep sleep Inducing

Testing the Sleep-Inducing Effect of 0.25 Hz Head Rocking

Experimental environment :

- Subjects: 6 healthy males (23.2 ± 2.0 years old)
- Limit: 0 to 6 hours of sleep the day before
- Content: 1-hour nap from 14:30
- Allow a week between normal and deformable pillow

Measurement:

- Measuring instruments (bio-amplifiers): Polymate V / Polymate Mini.

Sampling frequency: 1000 Hz

- **EEG** (Electrodes at O1 and A2 according to 10/20 method)
- **ECG** (Electrode attached based on 3-point induction)
- **Subjective assessment** (Karolinska sleep scale and visual analog scale)

EEG→Sleep latency
ECG→Heart rate variability and parasympathetic index
Subjective assessment
→ Pre-Experiment Sleepiness, Post-Experiment Changes, and Pillow Preferences and Performance Evaluation

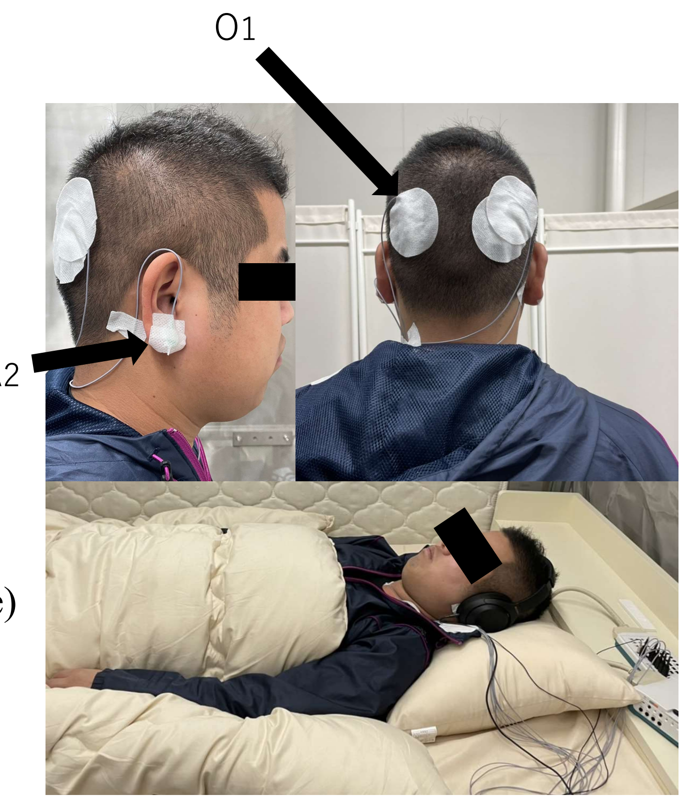


Fig. Experimental Scene

Analysis Method

EEG analysis way

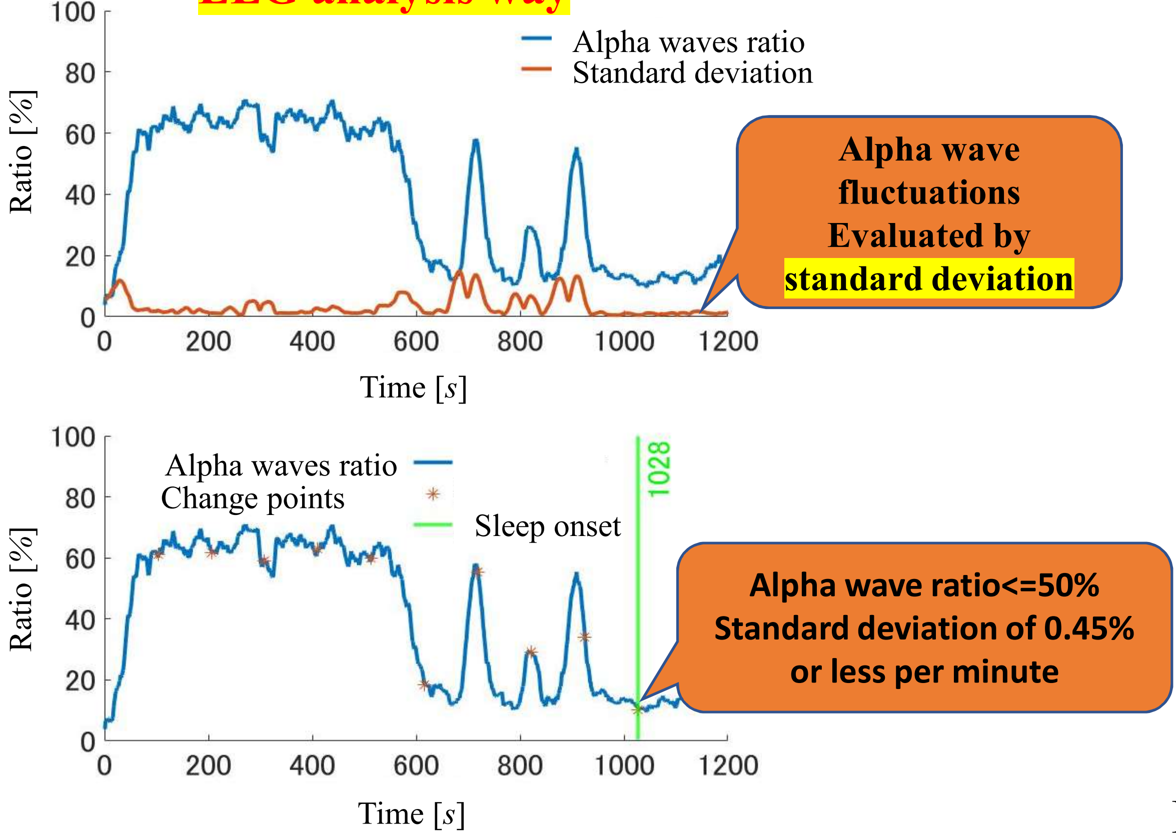


Fig. Calculate sleep onset

ECG analysis way

$$nHF = \frac{HF}{LF + HF}$$

LF: 0.05 to 0.20 Hz bandwidth power
HF: 0.20 to 0.35 Hz bandwidth power

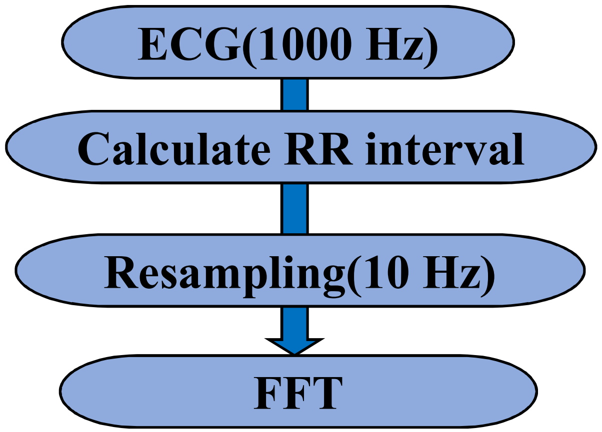


Fig. Calculate parasympathetic nerve indices

Results

Results by EEG

Table. Sleep latency per subject

	1	2	3	4	5	6	Average
Normal(Sleep latency[s])	307	410	205	1028	719	1234	651
Deformable Pillow([s])	719	205	307	307	410	925	479
Difference in sleep latency[s]	-412	205	-102	721	309	309	172
Improvement rate [%]	-134	50	-50	70	43	25	26

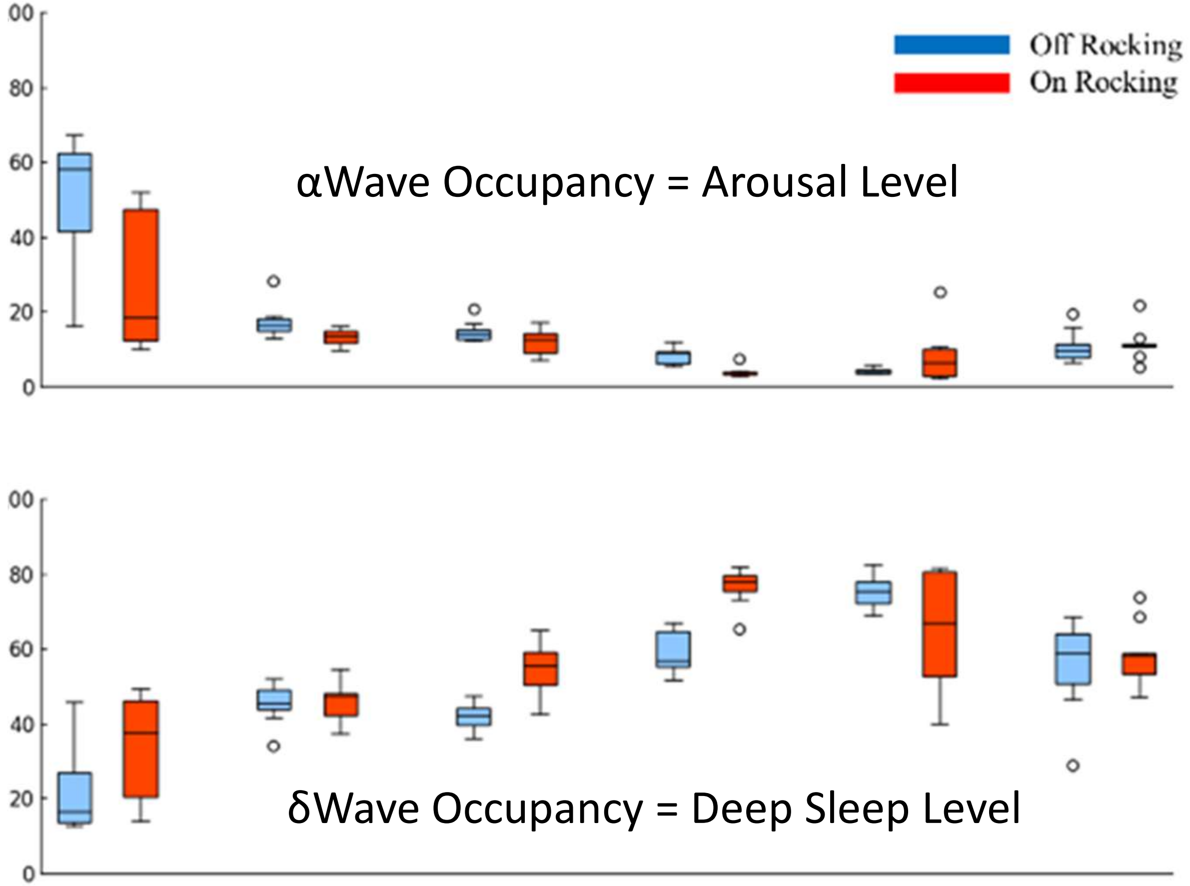
Results by ECG

Table. Average per subject of parasympathetic index[*1]

Subjects	1	2	3	4	5	6	Average
Normal(nHF)	0.19	0.14	0.23	0.10	0.06	0.10	0.136
Deformable Pillow(nHF)	0.17	0.16	0.20	0.11	0.08	0.14	0.143

Sleep latency shortened in 4 out of 6 patients, **2.9±5.9 min** on average
Parasympathetic index high in 4 out of 6

Results



Soft actuators change the physiological state of a Human due to the rocking effect

Soft Robotics Actuator for Human

Q6:Consider soft actuators that act on people.

Think of actuators that improve the human condition (can be mental or physical).

Today's Report

Work with your partner to complete all work
(You may submit the same answers as your partner)

Submit your work through Manaba+R
Deadline :12/25 at 17:00（Electrical File）
Or Submit now (Paper Document)

Merry Christmas & Happy New Year!