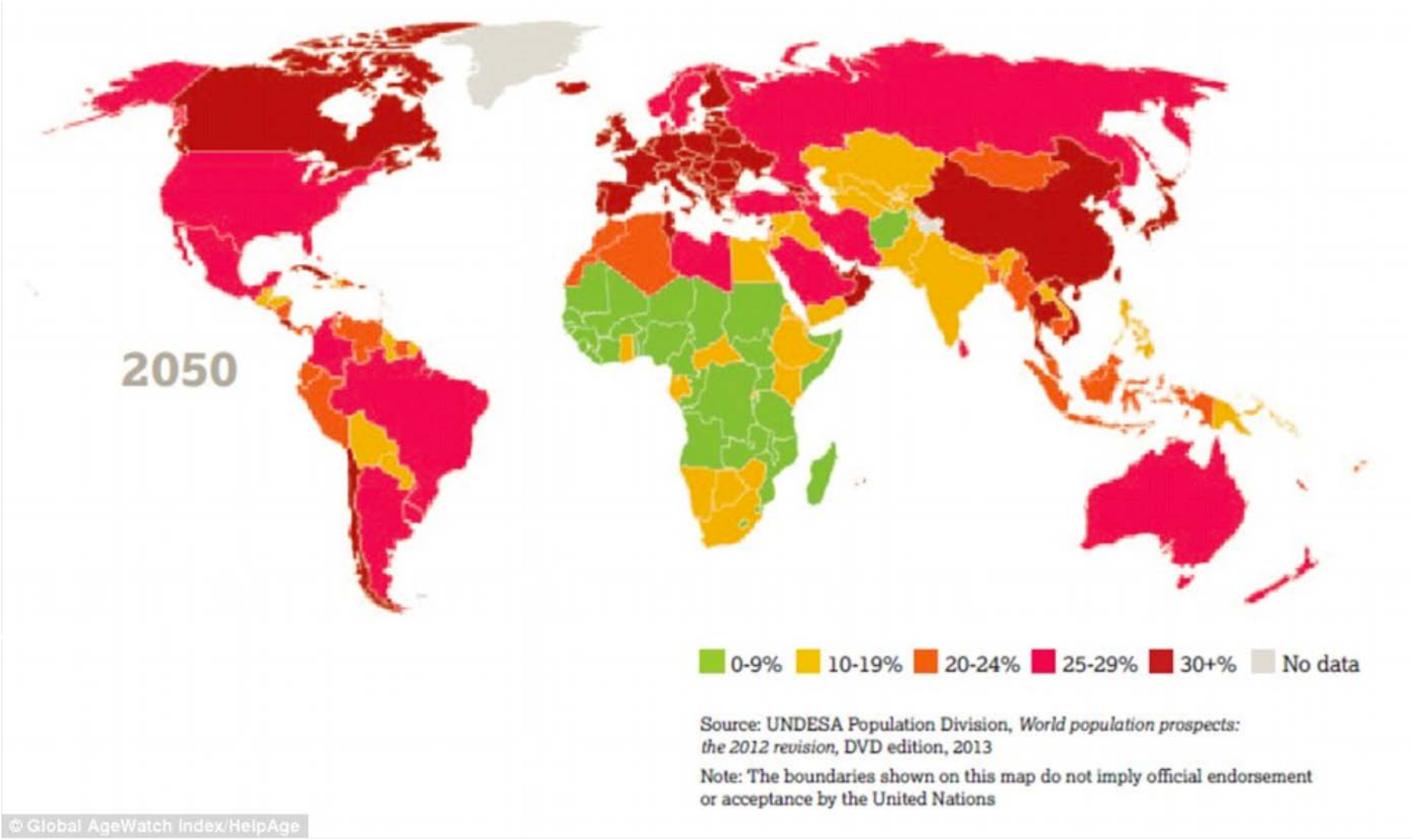
Sarah COSENTINO

Associate Professor
Faculty of Science and Engineering
International Center for Science and Engineering Program
Waseda University
Tokyo, Japan

Social participatory design of technologies for the Aging Society

DIJ TOKYO **DECEMBER 12, 2019**

AGING SOCIETY



[1] United Nations, 2013.

AGING POPULATION: WHAT ARE THE EFFECTS?

Decrease in mental and physical abilities:

- Decrease in overall Quality of life (QoL)
- Decrease in overall productivity
- Increase strain on healthcare system

Burden for the society as a whole

[1] M. Fougere and M. Merette. "Population ageing and economic growth in seven OECD countries" *Economic Modelling*, 16(3), pp. 411-427, Aug. 1999

[2] D. Bloom, D. Canning, G. Fink "Implications of population ageing for economic growth" *Oxford review of Economic policy*, 26(4), pp. 583-612, Dec. 2010

AGING POPULATION: DIFFERENT NEEDS

Various stages of aging conditions:

- Healthy and active → prevention
- Mentally healthy
  - Frail but self-sufficient → monitoring
  - Not self-sufficient → continuous care
- Mental conditions
  - Light, non-threatening → support
  - Severe degeneration → continuous care

BETWEEN NEEDS AND SOLUTIONS

- Prevention
  - Continuous training required
  - Subjective training estimation
- Monitoring
  - Logistics problems
  - Privacy concerns
  - Subjective needs estimation
- Support and care
  - Emotional distress
  - Subjective needs estimation

TECHNICAL

EMOTIONAL

ECONOMICAL

PROBLEMS

DIFFERENT NEEDS MEET TECHNOLOGY

Prevention

[1] Fitbit Official Site
https://www.fitbit.com/

Monitoring

[2] OMG Solutions
https://omg-solutions.com

...these solutions are not widely adopted and in use.

WHY?

Physical and Physiological support

[3] Swing Lift CoCoRo
https://www.orix.com/

Psychological support

[4] PARO Therapeutic Robot
www.parorobots.com/

USER-CENTERED ISSUES

Table 1 – Barriers to HIT adoption in the elderly.

- Familiarity and access
- Need for assistance
- Trust
- Privacy issues
- Design issues
  - Physical issues such as
    - Sight loss
    - Hearing loss
    - Decreased kinesthetic ability
  - Cognitive, navigation, and memory issues

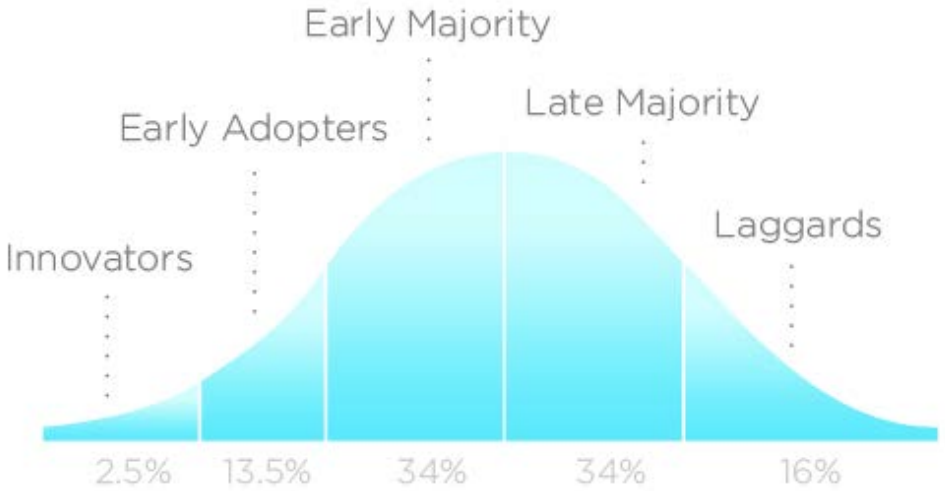
[1] S. H. Fischer, et al. "Acceptance and use of health information technology by community-dwelling elders." International journal of medical informatics 83(9), pp. 624-635, Sep. 2014

DIFFUSION OF INNOVATIONS THEORY

E. M. Rogers's Bell curve

[1] E. M. Rogers *Diffusion of Innovations.* Simon and Schuster, Jul. 2010

Development Assessment → Acceptance Adoption → Wide distribution



INNOVATION ADOPTION LIFECYCLE

TECHNOLOGY TO SUPPORT AGING

Low acceptance

TECHNOLOGY TO SUPPORT AGING

WHY?

COMMUNITY-CENTERED ISSUES

Several stakeholders

Scientists	Individuals	End users
Engineers	HC professionals	HC facilities
Technologists	Families	Govt policies
Designers	Economists	
	Authorities	

[1] S. T. M. Peek, et al., Factors influencing acceptance of technology for aging in place: A systematic review, *International Journal of Medical Informatics*, 83(4) , pp. 235-248, Apr. 2014

MY OBJECTIVE

Develop **user-centered** and **community-centered** technical solutions for the aging population with a **wide adoption rate**

USER-CENTERED TECHNOLOGY

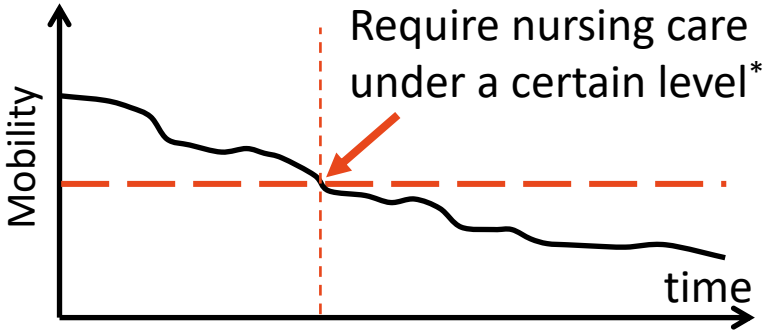
unobtrusive

seamless transition between

Prevention  Monitoring  Support

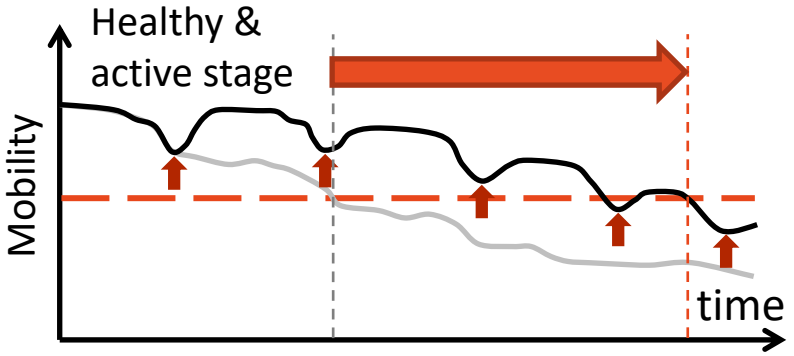
PREVENTION: IMPORTANCE OF MOBILITY ASSESSMENT

- Mobility decline with age
  - Inconstant slope (faster if disease or accident)[1]
  - Correlated with cognitive abilities



*Including but not limited to mobility

- Extend healthy and active time
  - Physical training or medical care
  - at the beginning of fast slope[1]
  - while still healthy and active[1]

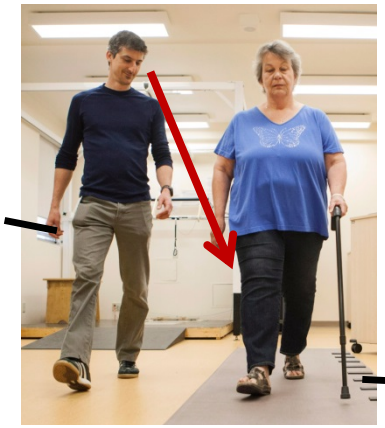


A frequent and reliable measurement for mobility is needed

[1] 厚生労働省 介護予防マニュアル(改訂版:平成24年3月)

PRACTICAL DIFFICULTIES

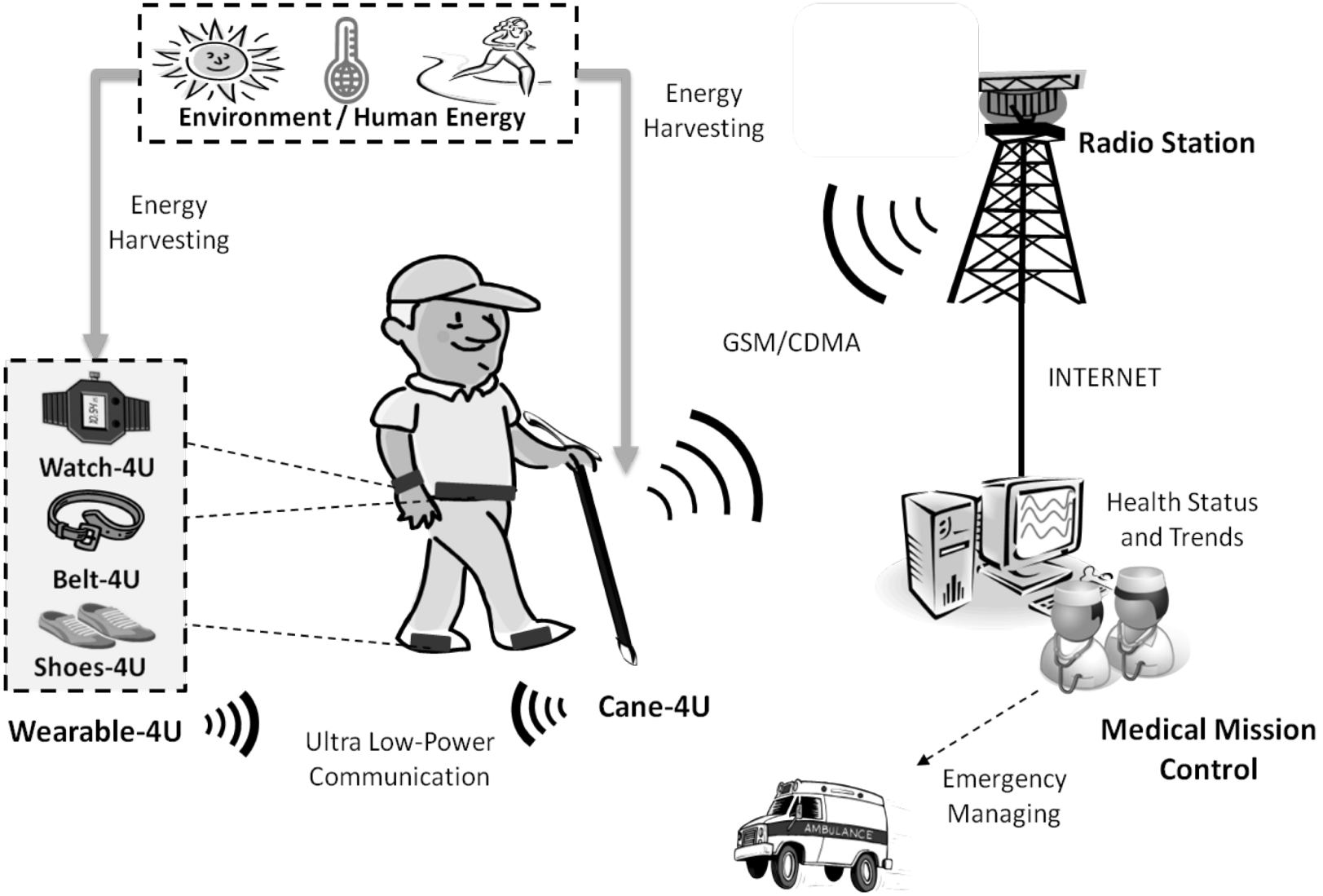
- Hospital or rehabilitation center
  - Standard tests (walking, sit-to-stand, one leg stance, etc.)
  - Subjective and objective assessment



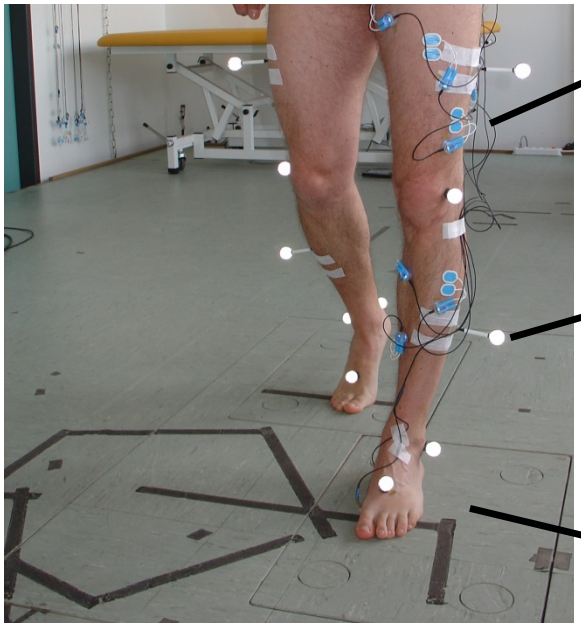
  - Problems
    - Prone to subjective human error
    - Costly: mainly for severe problems
    - Not easily accessible in daily life
    - Assessment for cognitive abilities is separated

4U

Unlimited, Ubiquitous, Universal, User-Friendly wearable monitoring system for the activity and vital parameters of older adults.



AUTOMATIC MOBILITY MEASUREMENTS

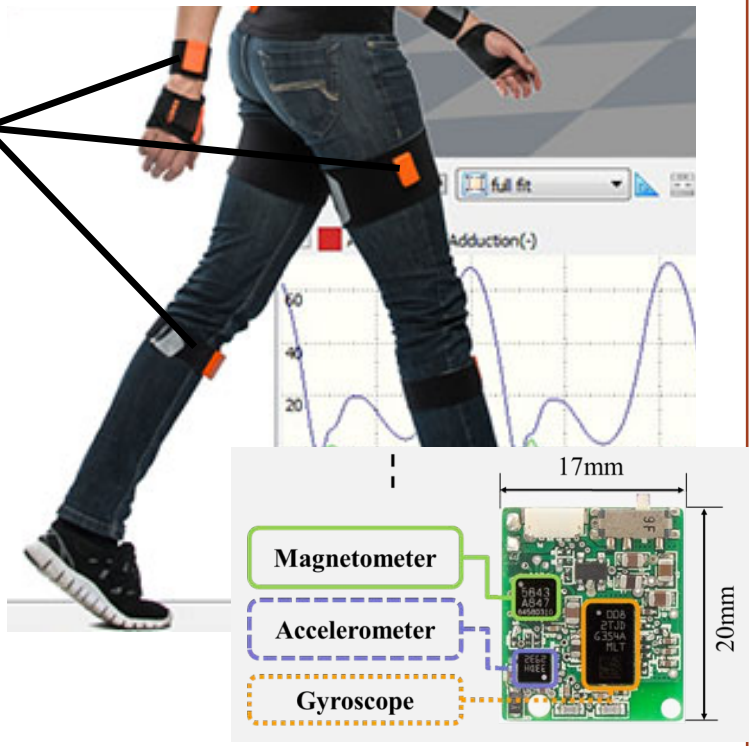


EMG[13]

Marker[14]

Force plate[15,16]

IMU



Limitations of lab-based:

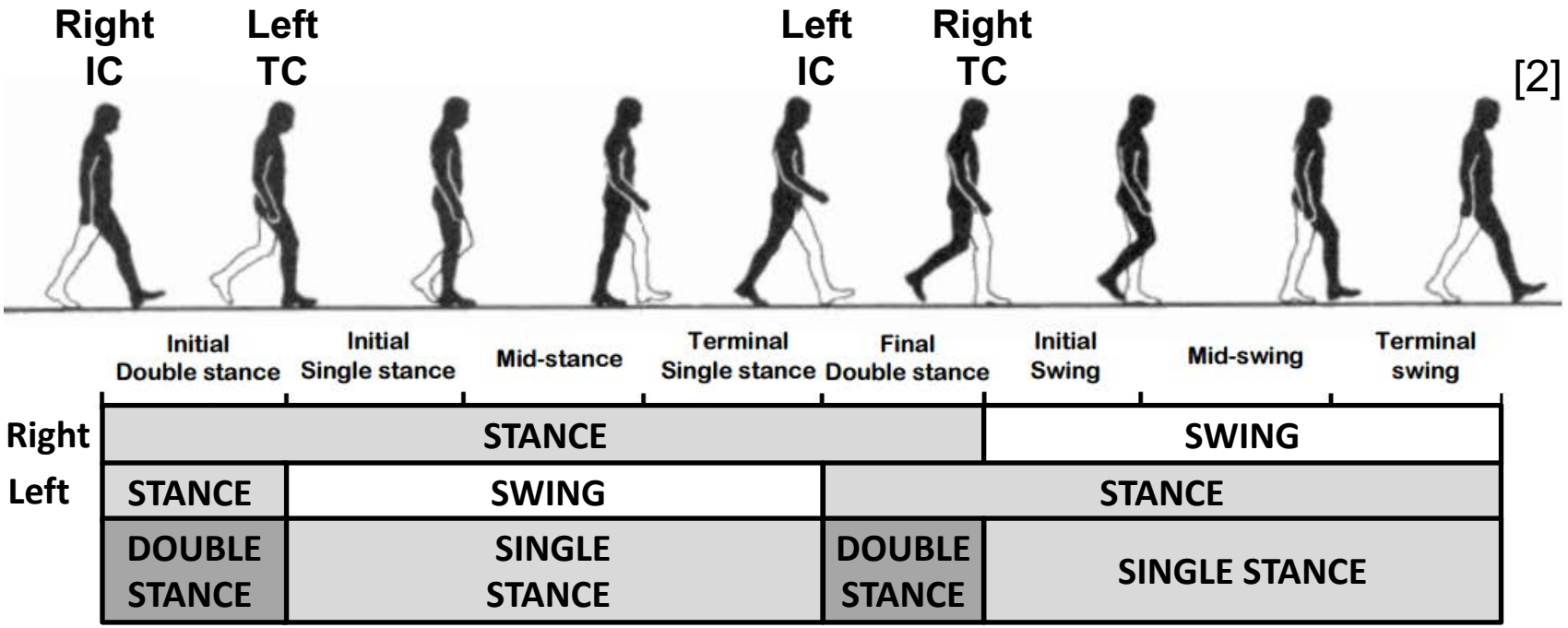
Expensive
Long setup time
Limited working space

Advantages of IMU:

Cheap (also in smart phone)
Short setup time
Unlimited working space

[13] Runge C F, 1999. [14] Mayagoitia R E, 2002. [15] da Silva R A, 2013. [16] Zhang S, 2013.

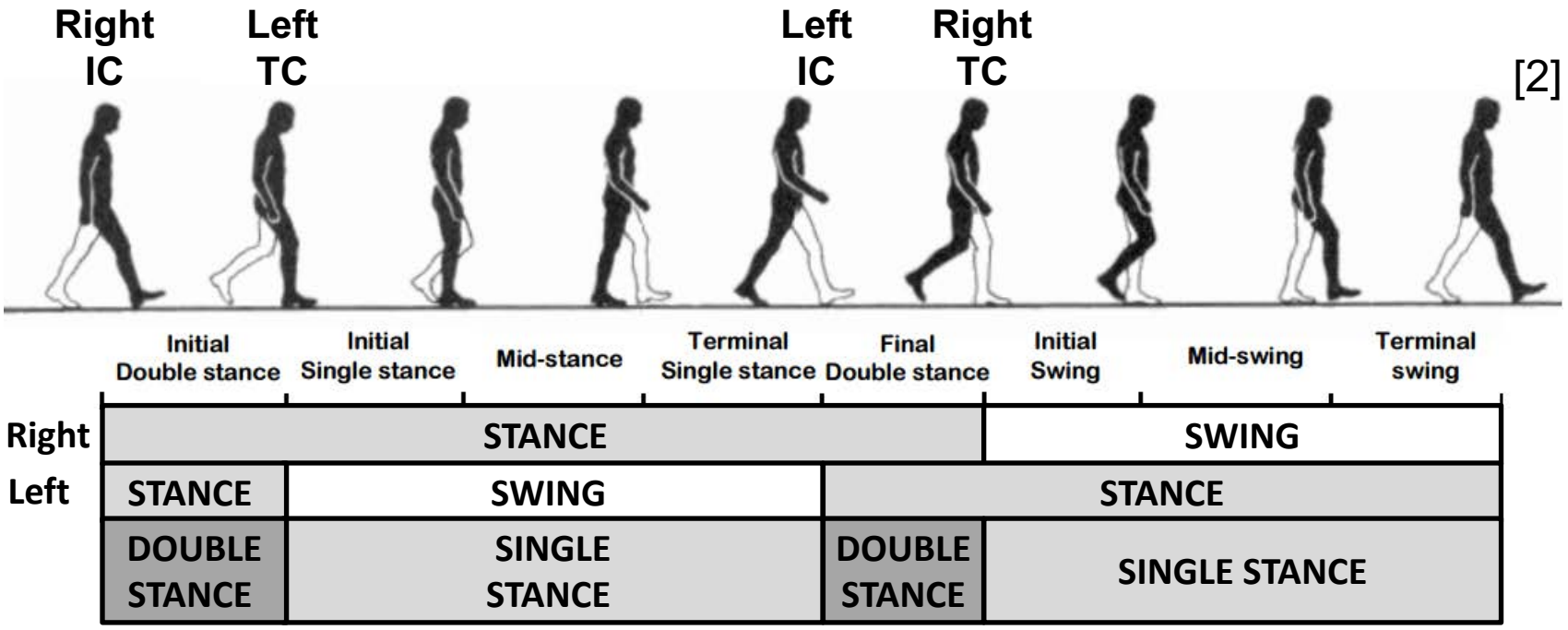
GAIT EVENTS AND TEMPORAL GAIT PARAMETERS



- Gait event
  - Initial Contact (IC): heel strike in normal walking
  - Terminal Contact (TC): toe off in normal walking
- Fundamental for temporal gait parameters

[2] Martín-Félez, 2011.

TEMPORAL GAIT PARAMETERS



- Stride time $IC_{i+1} - IC_i$
- Stance phase duration $TC_i - IC_i$
- Swing phase duration $IC_{i+1} - TC_i$
- Double stance phase duration $TC_{l/r} - IC_{r/l}$

[2] Martín-Félez, 2011.

MOBILITY AND COGNITIVE CORRELATED ANALYSIS

Single-task (ST)

Walking straight for 7m

Dual-task (DT)

Walking while back counting by 7 from a random number between 90 and 100

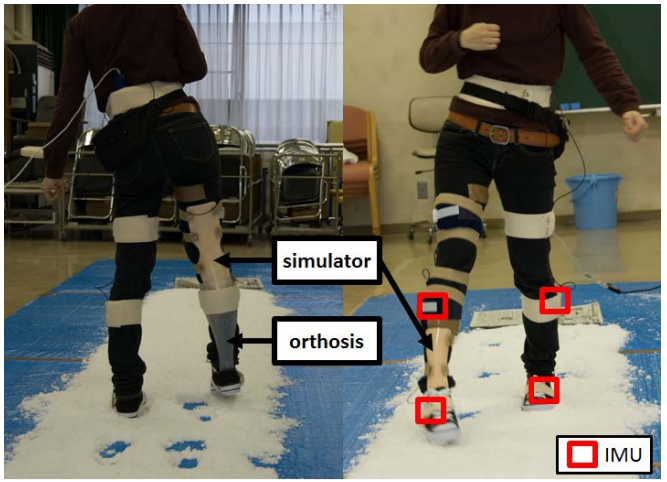
Multi-task (MT)

Walking while back counting plus holding a cup of water

100+ older adults (aged over 65)

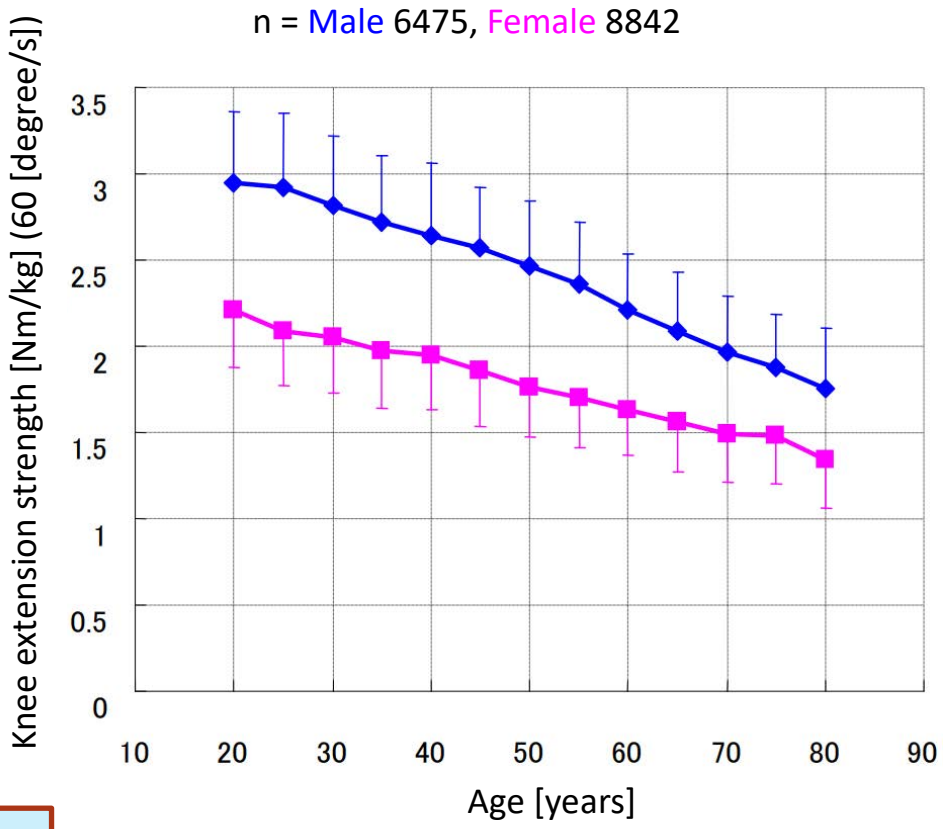
RELIABILITY AND ACCURACY

- Algorithms based on angular velocity of shanks or feet have been tested under:
  - Parkinson's disease (PD)
    - Shank-based TC: -8.7±12.5ms IC -2.9±26.8ms
  - Spinal injury
    - Shank-based TC: -53±11ms IC 61±10ms
    - Foot-based TC: -17±18ms IC 27±28ms
  - Ankle orthosis
  - Walking on snow



MUSCLES AND MOBILITY

- Relation between muscle strength and mobility: Knee extensors strength is most important.[1]
- Knee extensors strength decrease significantly with aging.[2]



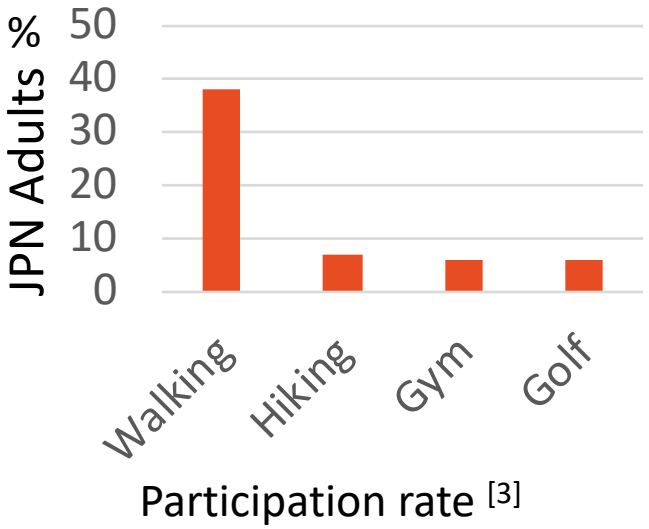
To <u>delay</u> the loss of knee extensors strength

Knee extensor strength training device is needed

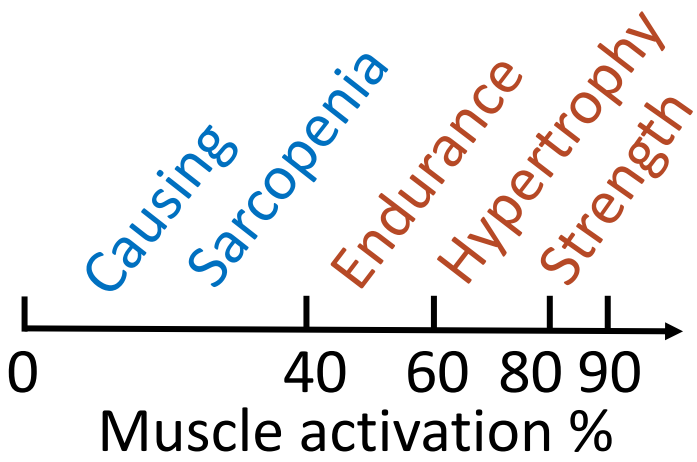
[1] Todd M. Manini et.al. "Knee extension strength cut points for maintaining mobility"
[2] Yokohama Sports medical center "SPS medical measurement introduction"

MUSCLE TRAINING

- Walking is the most popular training[3]
  - ✕ KXM is not trained
  - ✕ Unrecognized training insufficiency[4]



Participation rate [3]

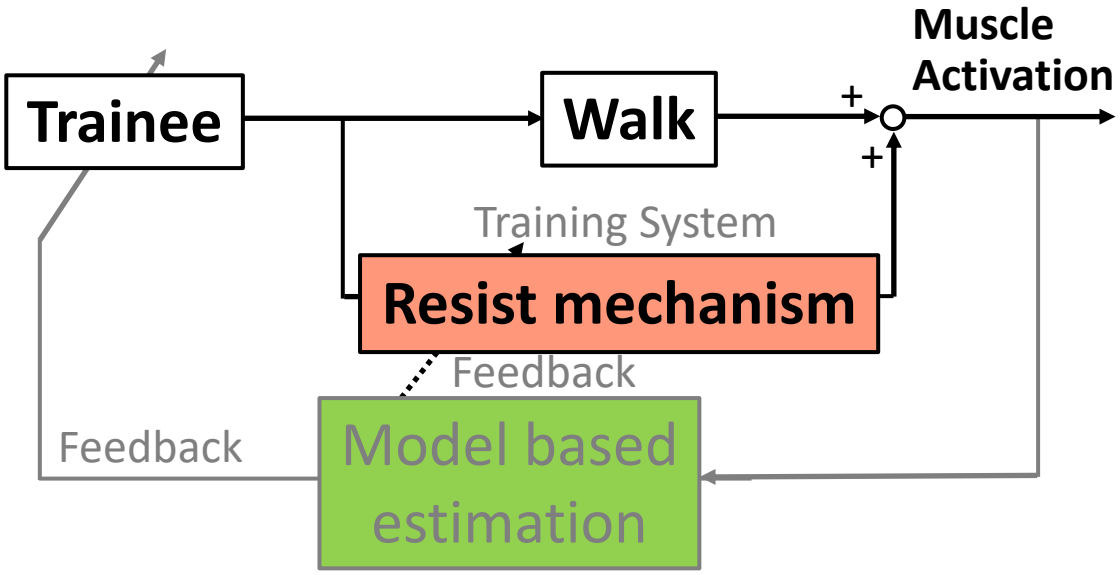


① ***Enhance KXM training***
② ***Visualize muscular activity***

[3] 総務省・平成24年統計からみた我が国の高齢者

[4] D. R. Bassett, “Device-based monitoring in physical activity and public health research”, 2012.

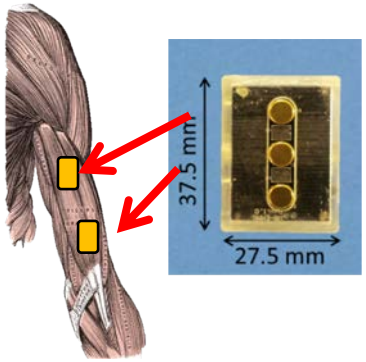
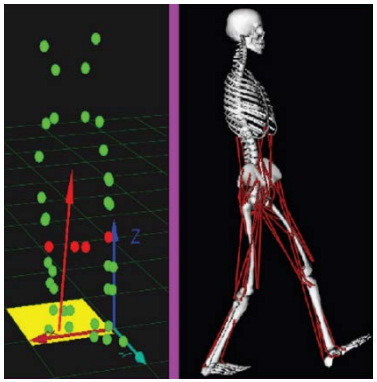
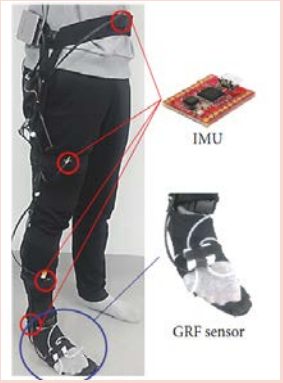
LONG TERM OBJECTIVE



Typical Application :
Healthy adult walk with training device for 30 minutes everyday.

Development of a smart adaptive system for knee extension muscle training during walking.

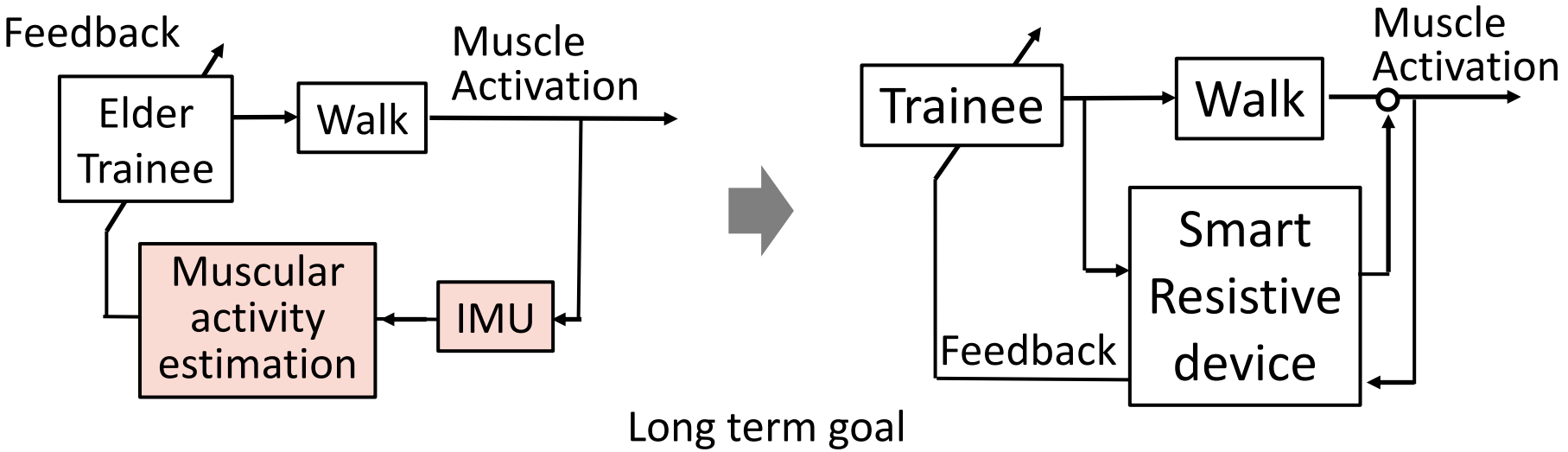
MUSCLE ACTIVITY ESTIMATION: STATE OF ART

	Electromyography (EMG)[1]	Optical Motion Capture[2]	IMU + GRF [3] Inertial Measurement Unit / Ground Reaction Force
			
Merit	Direct measurement of muscular activity	Measurement of whole body link model with high accuracy	No work space limitation
Limitation	Direct placement on skin Artifact on skin surface	Work space limitation Long setup time	Complex multi-sensor fusion

A simple muscular activity estimation is needed

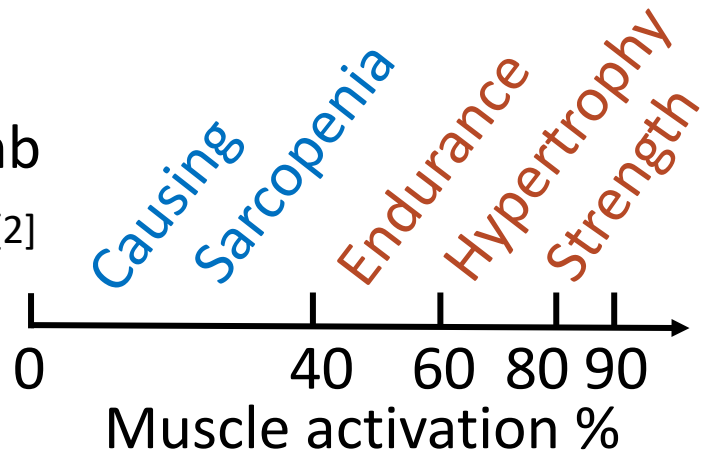
[1] O. C. J. Lippold "The relation between integrated action potentials in a human muscle and its isometric tension", J Physiol. Jun 28, 1956; 132(3): 677–681.
[2] M. Karimi and M. Kavyani, "Scoliosis curve analysis with Milwaukee orthosis based on Open SIMM modeling," J.Craniovertebral Junction and Spine, 6(3), 2015
[3] S. Kim, K. Ro, and J. Bae, "Real-time estimation of individual muscular forces of the lower limb using wearable sensors," IEEE AIM 2015

LONG TERM GOAL AND OBJECTIVE



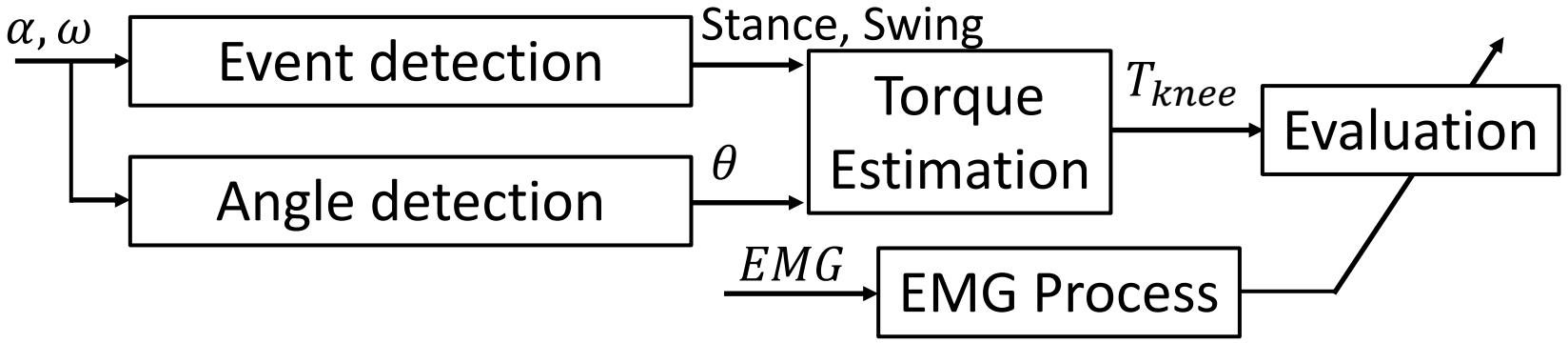
Objective: Muscular activity estimation ONLY BY IMU

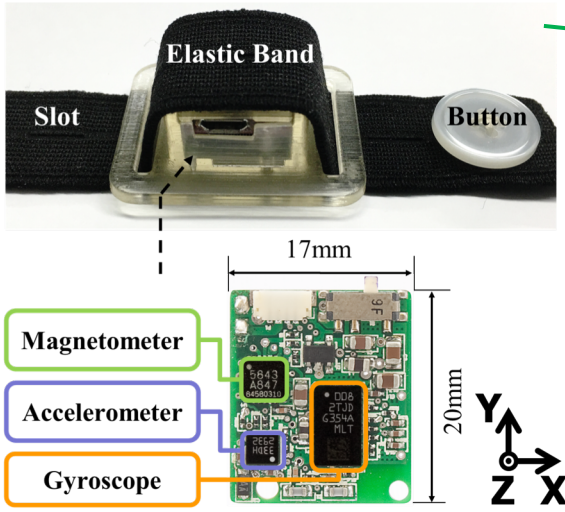
- Simple and low cost estimation
- Target: Normal walk, Fast walk, Stair climb
- Required accuracy: 4 levels detection [1][2]

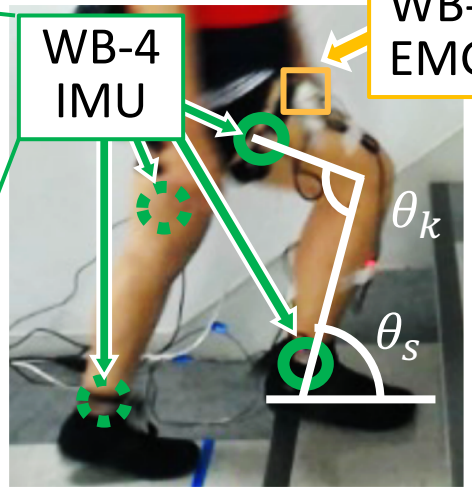


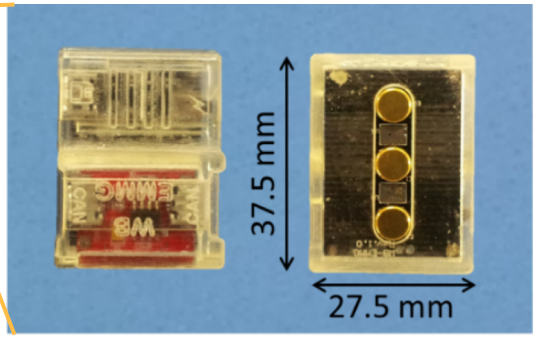
[1] Supertraining. Supertraining Institute, 2003
[2] M. Yamada, “サルコペニア : 予防と改善”, 2013

MATERIALS AND METHOD



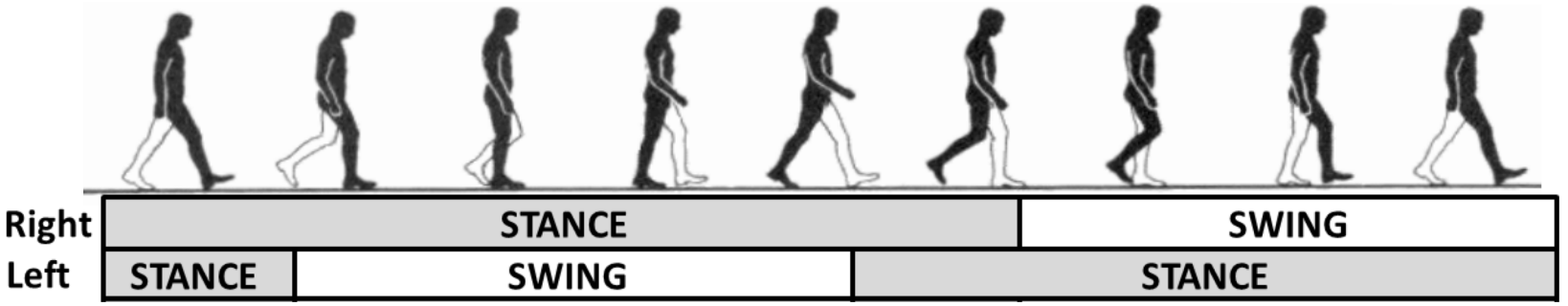






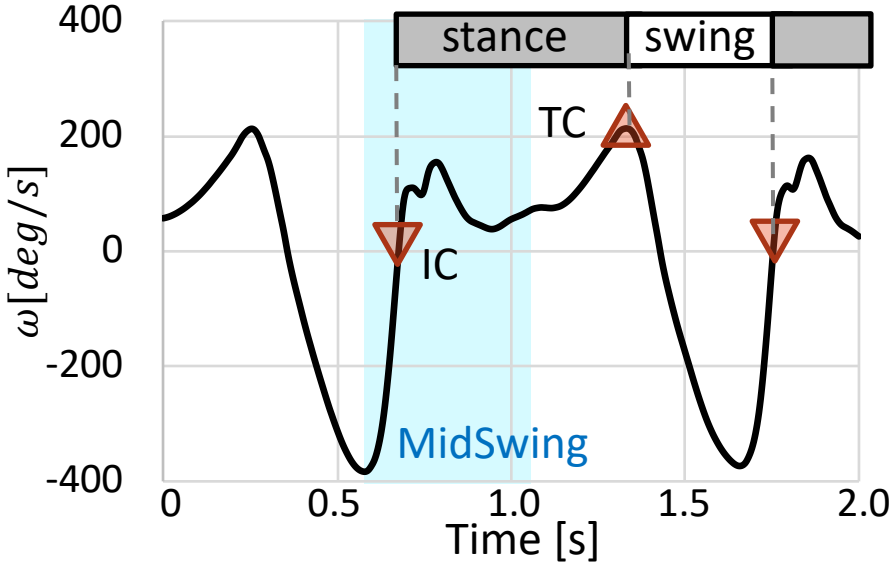
	Accelerometer (LIS331DLH)	**Gyroscope** (LYPR540AH)	**Magnetometer** (HMC5843)
Axis	3-axis	3-axis	3-axis
Range	±2/±4/±8 [G]	±400/±1600 [deg/s]	±4 [Gauss]
Resolution	1/2/3.9[mG/digit]	3.2/0.8[mV/dps]	12 [bit]
Bandwidth	25/50/500[Hz]	140[Hz]	50[Hz]

GAIT EVENTS DETECTION

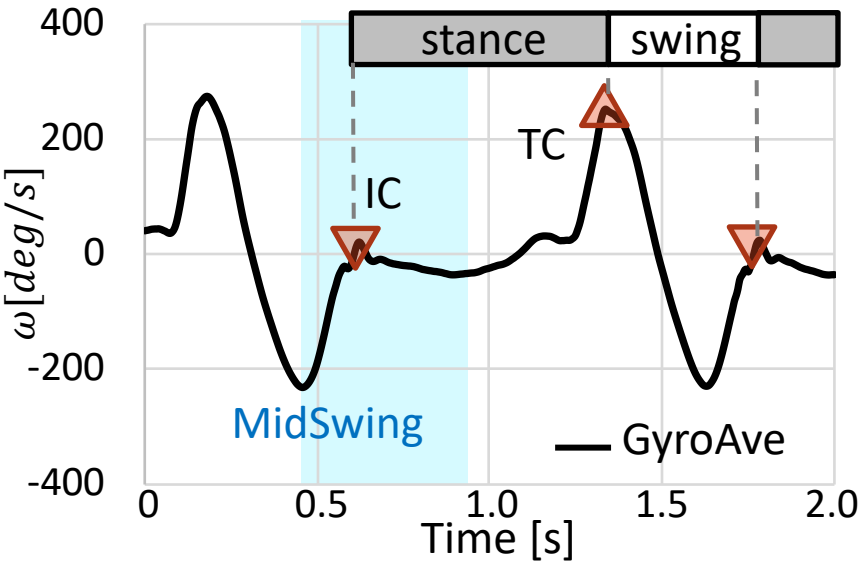


- Calculate walking features from gait event
  - Initial Contact (IC) : 1st cross-zero point
  - Terminal Contact (TC) : 1st local maxima

Normal walk[1]



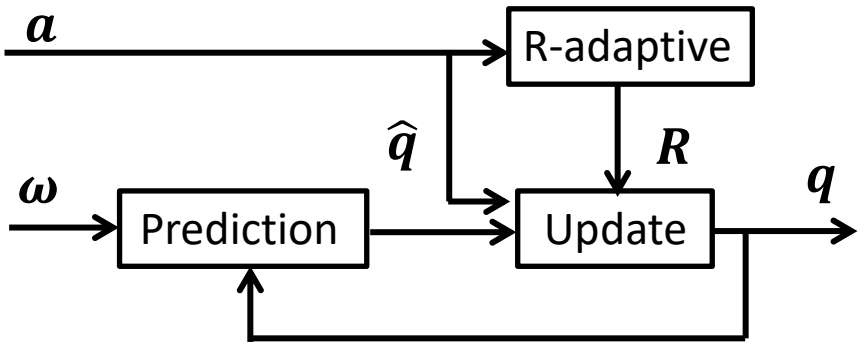
Stair ascent



[1] R. Kasai, et al "Reliability of stride length estimation in self-pace and brisk walking with an inertial measurement unit on shank", IEEE ICMA 2017

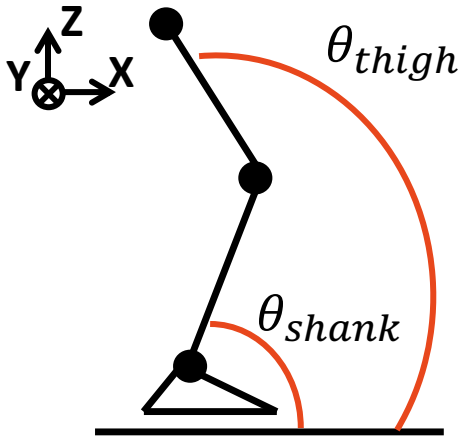
KNEE ANGLE DETECTION

- Extended Kalman Filter
  - Improve rotation detection by sensor fusion
- Quaternion
  - Avoid singularity



$$\boldsymbol{q} = [q_1, q_2, q_3, q_4]^T \quad (1)$$

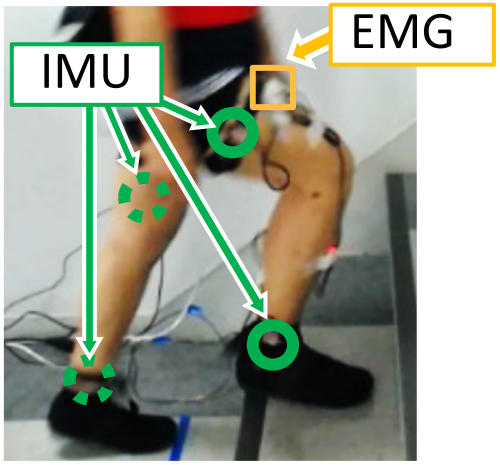
$$\theta_i = \arccos(2(q_1 q_2 - q_3 q_4)) \quad (3)$$



$$C_n^b(q) = \begin{bmatrix} q_1^2 - q_2^2 - q_3^2 + q_4^2 & 2(q_1 q_2 + q_3 q_4) & 2(q_1 q_3 + q_2 q_4) \\ 2(q_1 q_2 - q_3 q_4) & -q_1^2 + q_2^2 - q_3^2 + q_4^2 & 2(q_2 q_3 + q_1 q_4) \\ 2(q_1 q_3 - q_2 q_4) & 2(q_2 q_3 - q_1 q_4) & -q_1^2 - q_2^2 + q_3^2 + q_4^2 \end{bmatrix} \quad (2)$$

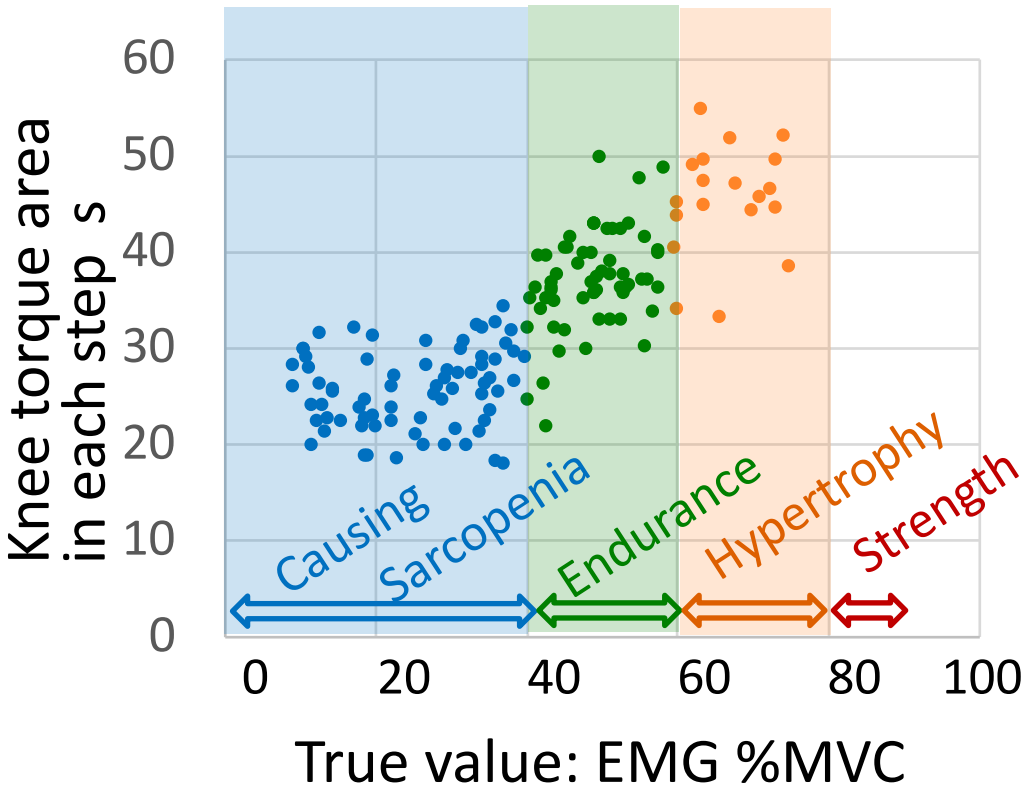
EXPERIMENT WITH KAWAKAMI LAB.

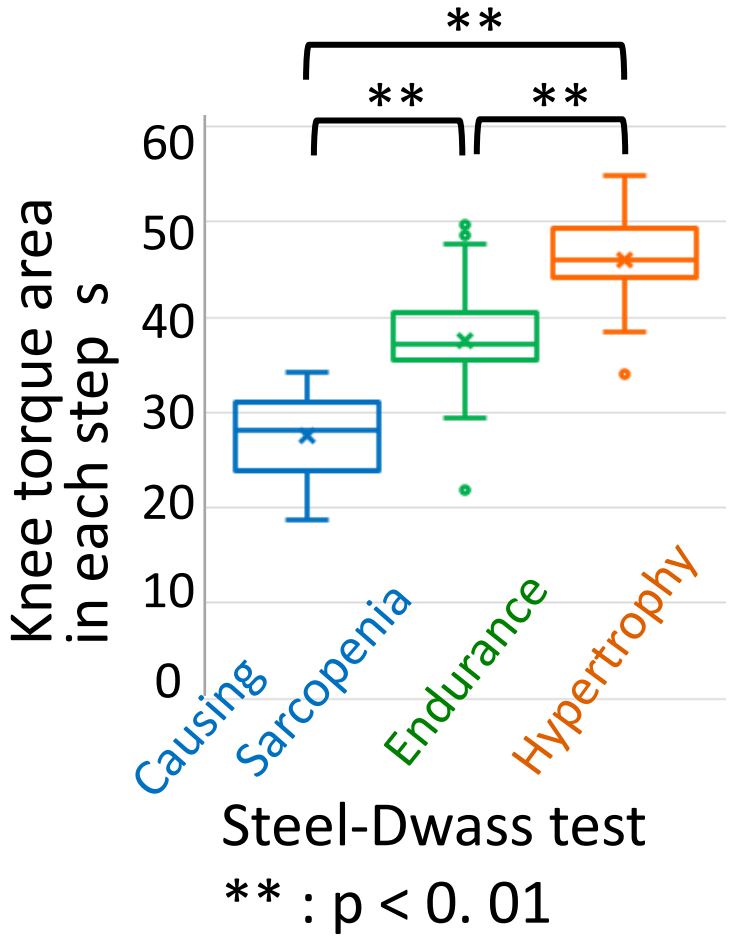
- Purpose
  - validation of the proposed method
- Participants
  - 28 Healthy older adults
    - 14 males, 14 females
    - Age: 65 – 84 y.o.
    - Weight: 56 ±9 kg
    - BMI: 23 ± 3
- Protocol
  - Stair climb 11steps ×2
  - Normal walk 5m ×2
  - Fast walk 5m ×2
  - Maximum Voluntary Contraction (MVC)



Normal walking

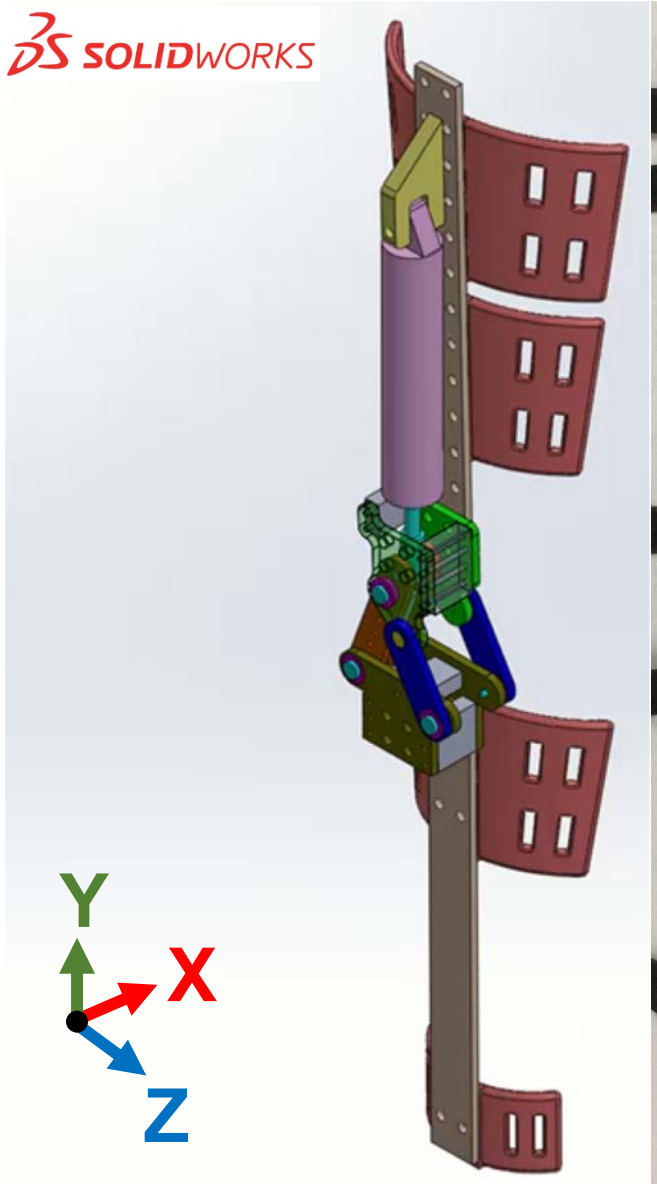
RESULTS: MUSCLE ACTIVITY ESTIMATION

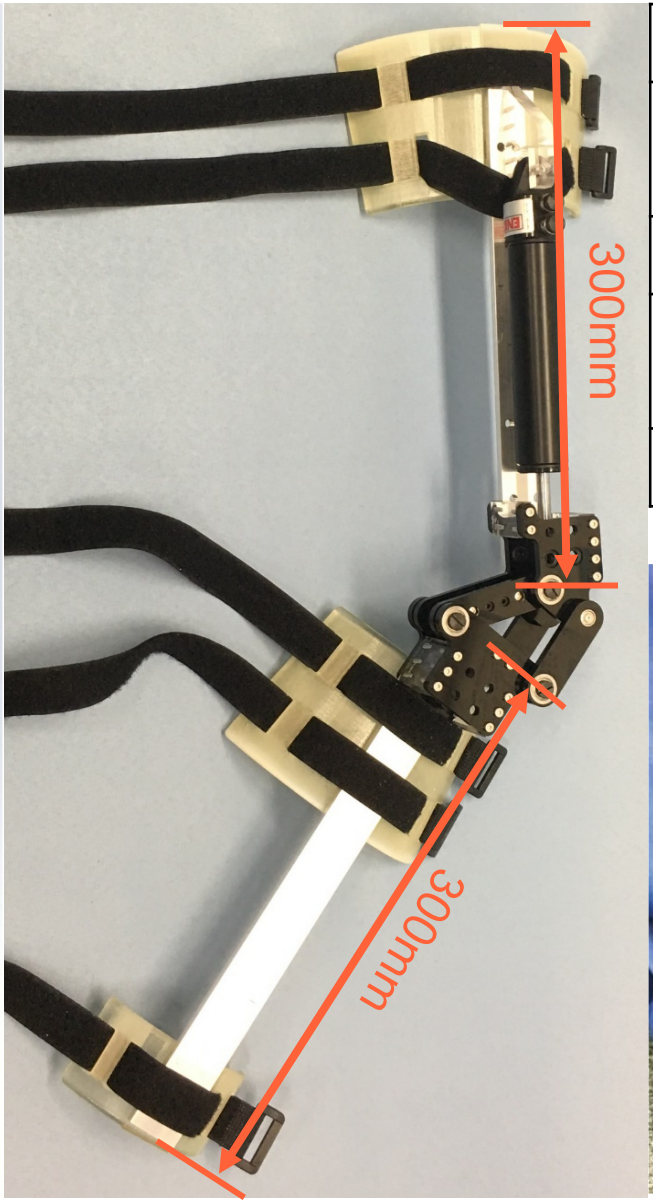




Significant difference for different training level

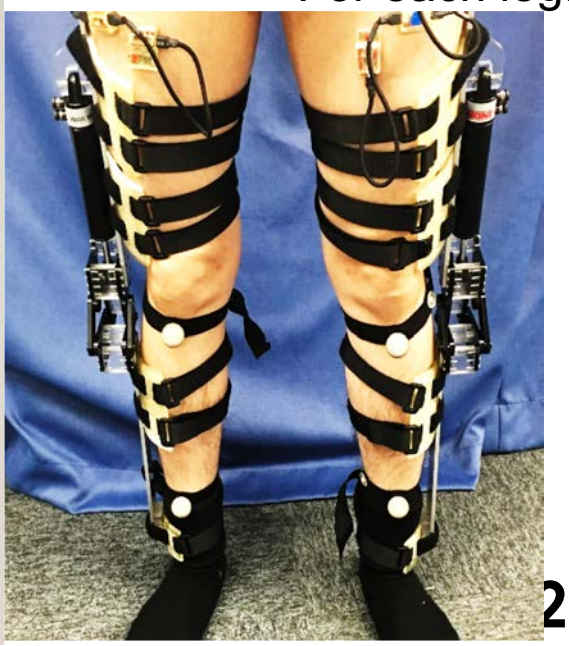
SMART KNEE EXTENSOR TRAINER





Parts*	Weight [g]
Linkage Mechanism	796
Coupling	349
Fitting bands	53
Total	1231

*For each leg.



COMMUNITY-CENTERED TECHNOLOGY

Providing support to the different needs of all the stakeholders

Healthcare professionals  Families  Elderly under continuous care

ROBOTS TO SUPPORT ELDERLY CARE

This is Fred Heuer, he woke up early as usual, had breakfast and took his meds this morning...

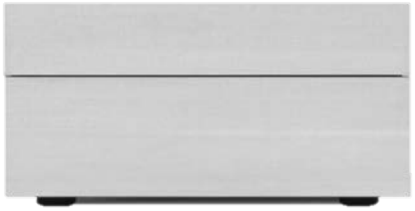
Hello Fred, how's going today?
Shall we have a walk?

Hello Pep, oh, the usual ups and downs.. Sure, let's go!

② **BlessBot**
Culturally adaptive

(German)

(Japanese)



① **AHA Trainer**

Session Recording...
Hans Reuter
- Sad face
- Slow moves
- Low physiological data

Paul Weber
- Happy face
- Confident attitude
- Physiological parameters in range

...

③ **MusicBot**

CAUSE

Several stakeholders

Scientists	Individuals	End users
Engineers	HC professionals	HC facilities
Technologists	Families	Govt policies
Designers	Economists	
	Authorities	

[1] S. T. M. Peek, et al., Factors influencing acceptance of technology for aging in place: A systematic review, *International Journal of Medical Informatics*, 83(4) , pp. 235-248, Apr. 2014

CAUSE

Several stakeholders

Scientists	Individuals	End users
Engineers	HC professionals	HC facilities
Technologists	Families	Govt policies
Designers	Economists	
	Authorities	

[1] S. T. M. Peek, et al., Factors influencing acceptance of technology for aging in place: A systematic review, *International Journal of Medical Informatics*, 83(4) , pp. 235-248, Apr. 2014

SOCIAL PARTICIPATORY DESIGN

- Social participatory design
  - Wide dissemination of preliminary study results
  - Organizations of meetings and discussions with each and every stakeholder
  - Analysis of different technical aspects
  - Analysis of different cultural aspects
  - Analysis of different social aspects
  - Analysis of different economic aspects

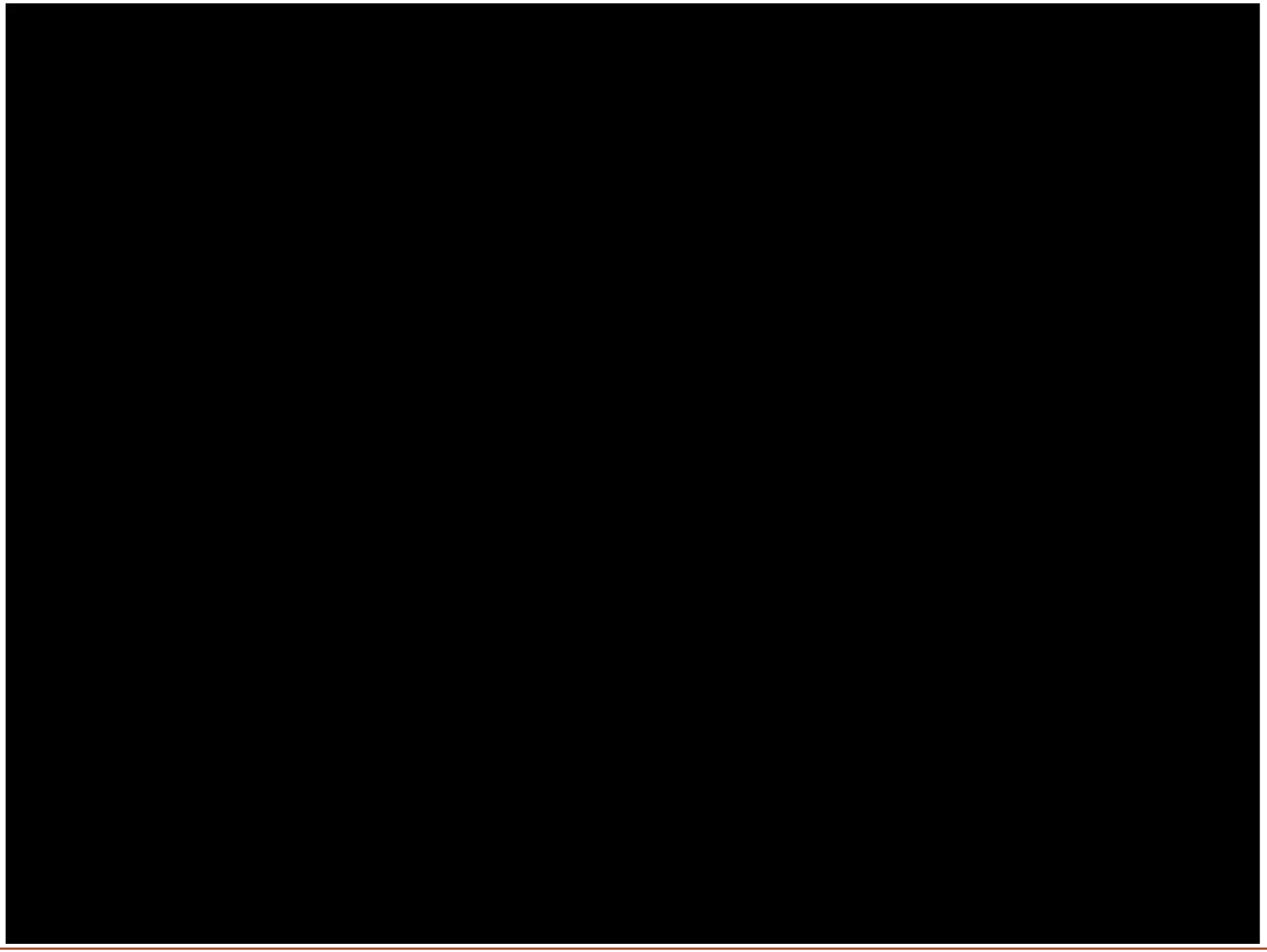
Technology adoption

[1] C. Spinuzzi, “The methodology of participatory design”, *Technical communication*, 52(2) , pp. 163-174, May 2005

RESEARCH COLLABORATIONS

- Demographic analysis for technology acceptance
- Social qualitative studies on Active Aging
- Organization of public workshops and discussions for Active Aging awareness
- Preliminary studies for technical requirements

10-WEEKS INTERVENTION IN CARE FACILITY

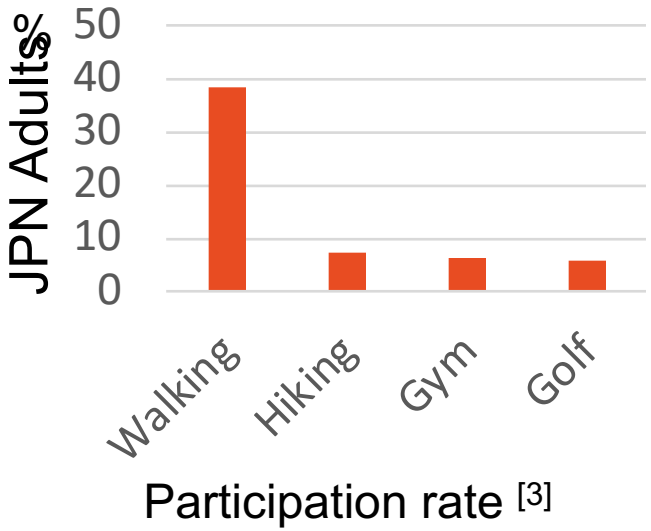


Thank you very much for your attention!

MY RESEARCH: STUDY OF AHA NEEDS

- People requiring care : 5million [1]
- Independence and muscles relation[2]
  - ***Knee Extension Muscles (KXMs) training***

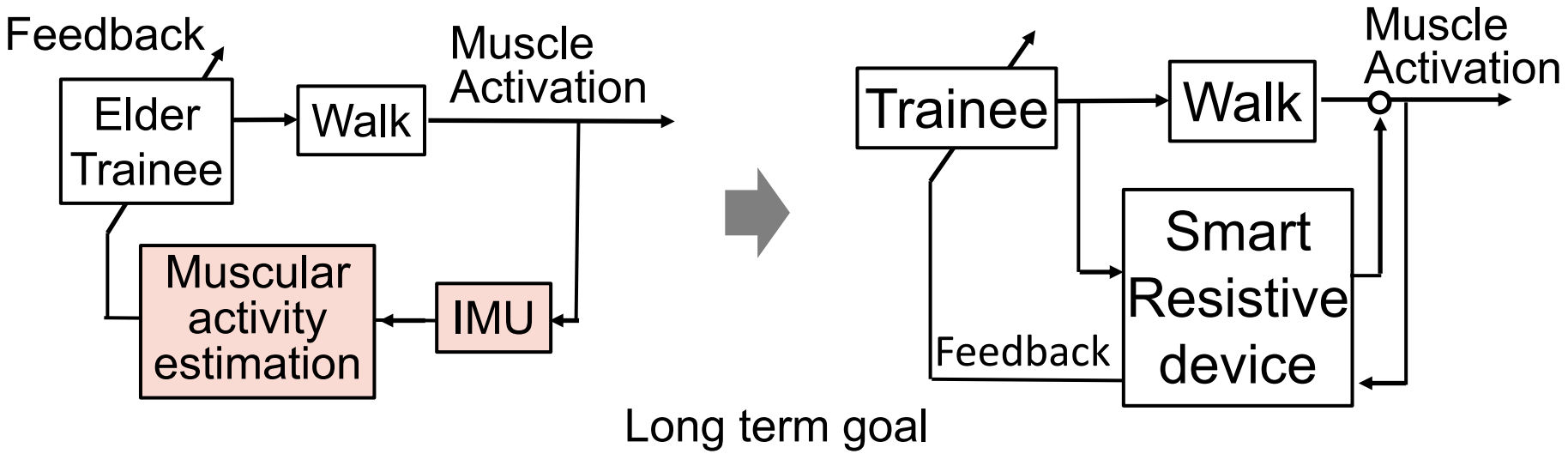
    is the most important
- Walking is popular training[3]
  - × KXM is not trained
  - × Unrecognized training insufficiency[4]



① ***Enhance KXM training***
② ***Visualize muscular activity***
are needed

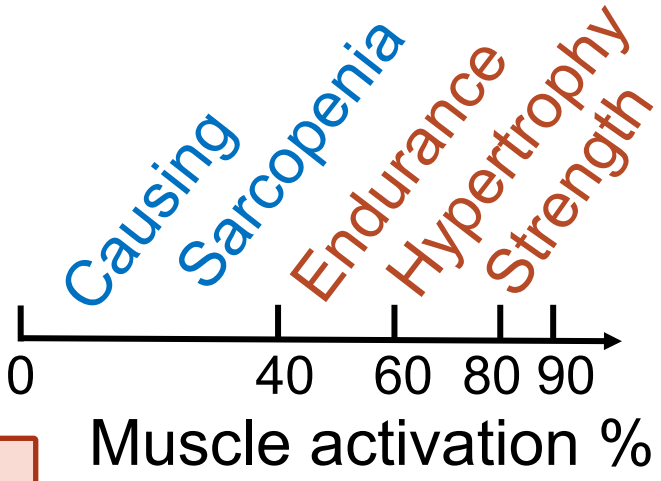
[1] 内閣府・平成27年高齢社会白書
[2] 浅川 康吉　高齢者における下肢筋力と起居・移動動作能力の関連性 1997
[3] 総務省・平成24年統計からみた我が国の高齢者
[4] D. R. Bassett, “Device-based monitoring in physical activity and public health research”, 2012.

DEVELOPMENT OF TECHNOLOGY FOR AHA



Objective: Muscular activity estimation ONLY BY IMU

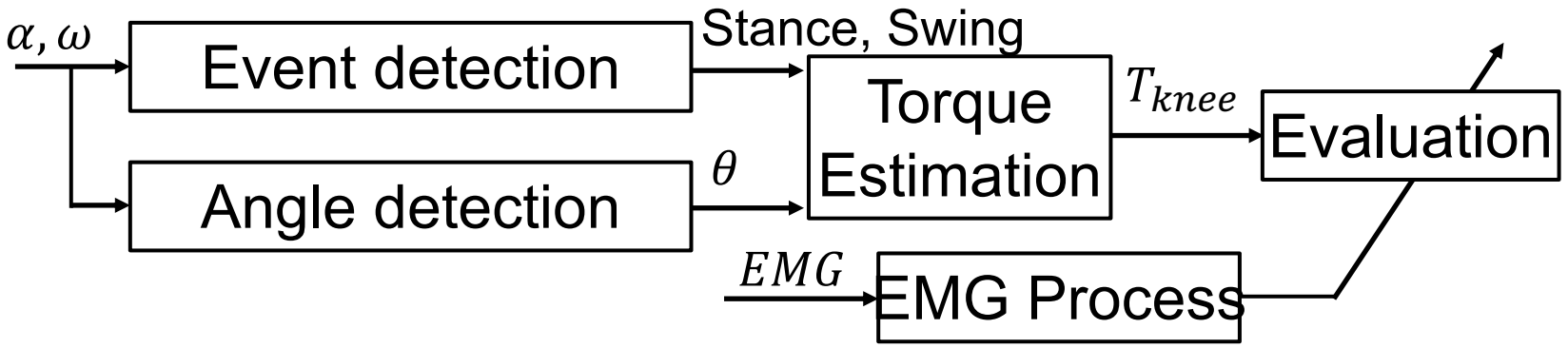
- Originality
  - not using EMG and GRF
  - simple and low cost estimation
- Target: Normal walk, Fast walk, Stair climb
- Required accuracy: 4 levels detection [1-2]

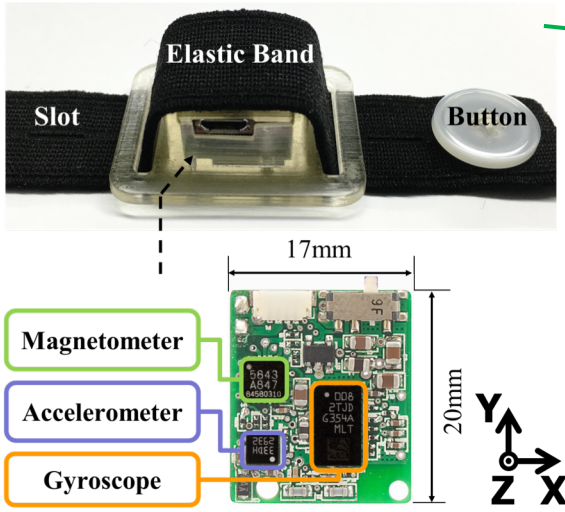


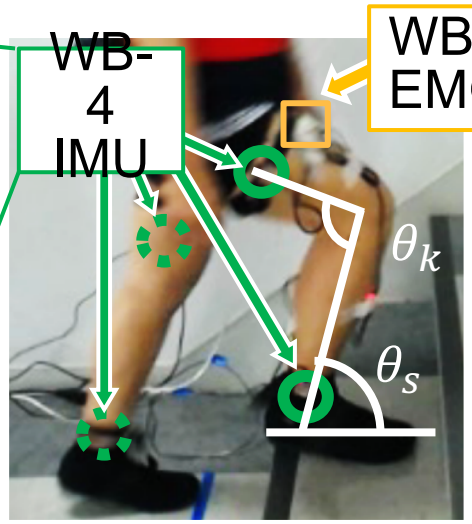
Knee torque estimation is needed

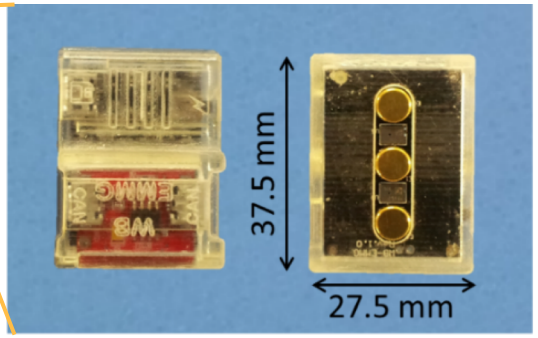
[1]Supertraining. Supertraining Institute, 2003 [2] M. Yamada, “サルコペニア：予防と改善”, 2013

DEVELOPMENT OF TECHNOLOGY FOR AHA





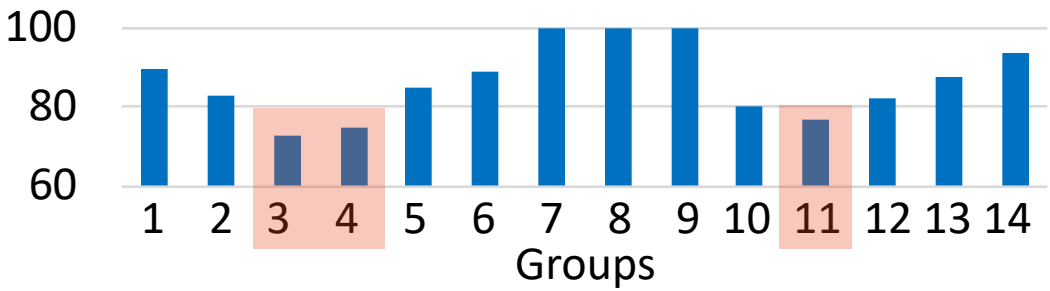




	Accelerometer (LIS331DLH)	**Gyroscope** (LYPR540AH)	**Magnetometer** (HMC5843)
Axis	3-axis	3-axis	3-axis
Range	±2/±4/±8 [G]	±400/±1600 [deg/s]	±4 [Gauss]
Resolution	1/2/3.9[mG/digit]	3.2/0.8[mV/dps]	12 [bit]
Bandwidth	25/50/500[Hz]	140[Hz]	50[Hz]

DISCUSSION

- 14-fold cross-validation
  - 13 groups data for training, 1 group data estimation

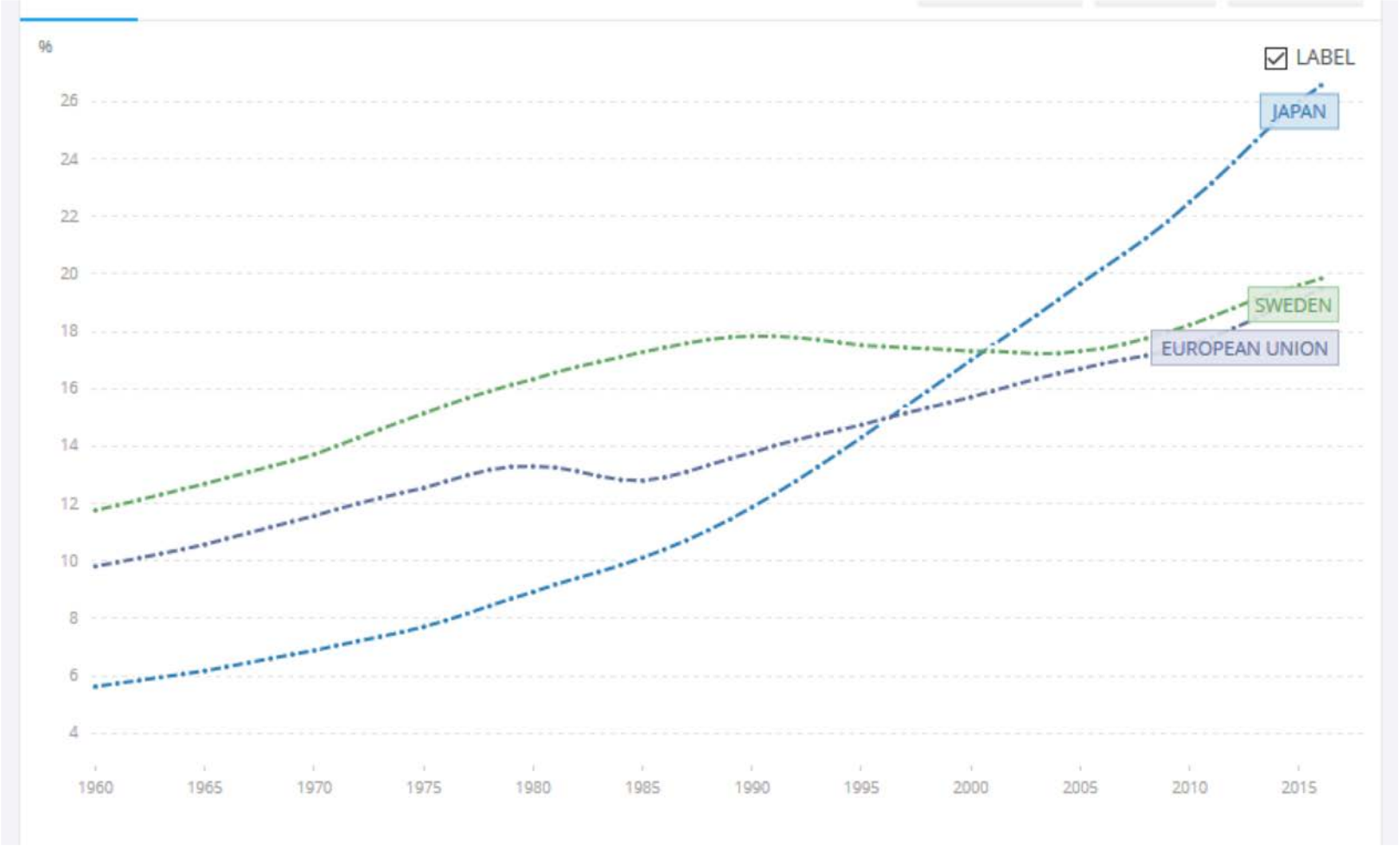
	Causing Sarcopenia – Endurance	Endurance – Hypertrophy
Threshold Nms/mkg	31.8 ~ 32.7	42.9 ~ 44.3
Estimation accuracy %		

- Discussion
  - Error causes
    - Longest or shortest leg ratio against body height
    - Highest BMI

Consideration of body parameters will improve the accuracy

THE WORLD: A AGING SOCIETY

Sweden, Japan: % of population > 65 years old

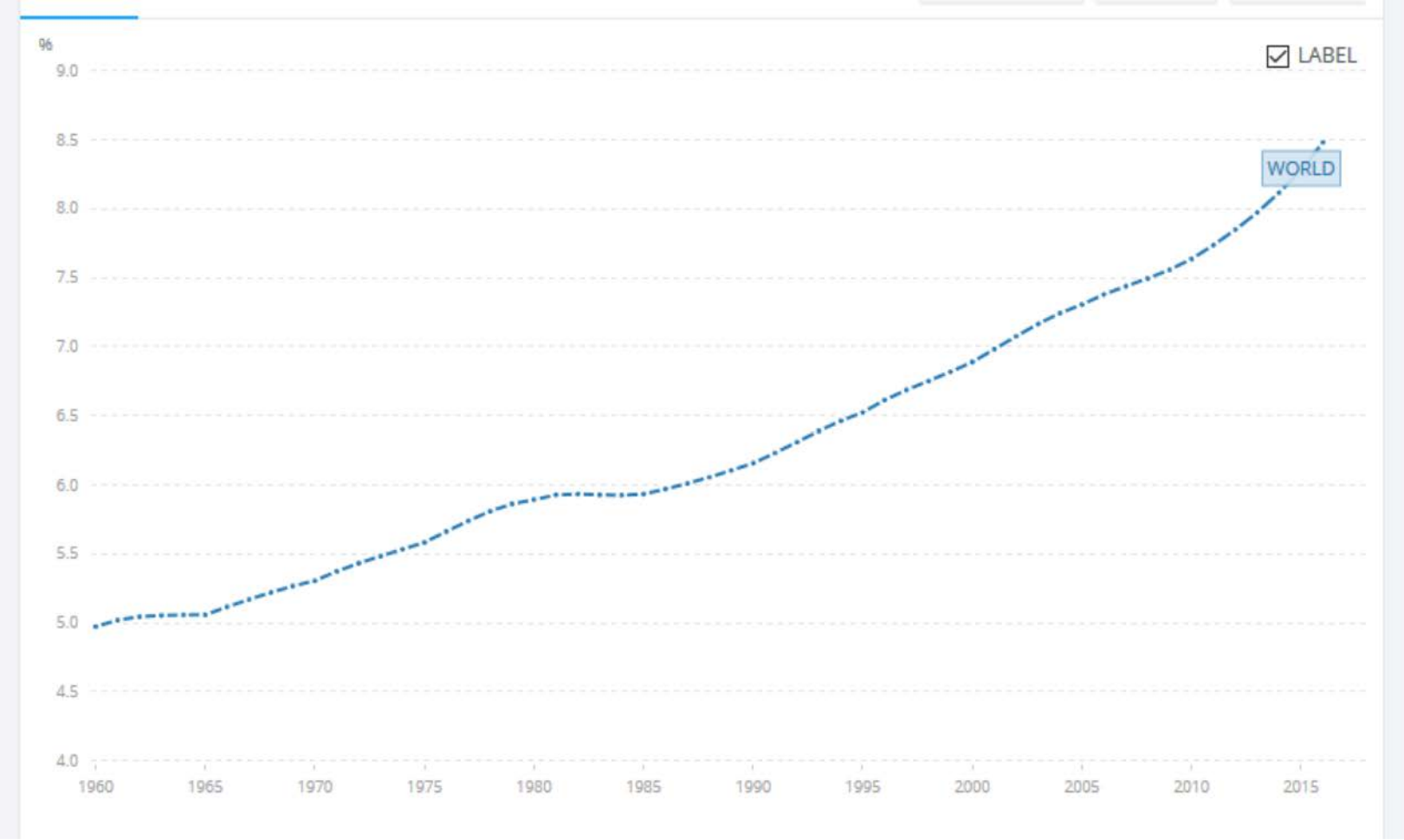


[1] The World Bank https://data.worldbank.org

SOCIAL ROBOTS FOR HEALTHCARE

THE WORLD: A AGING SOCIETY

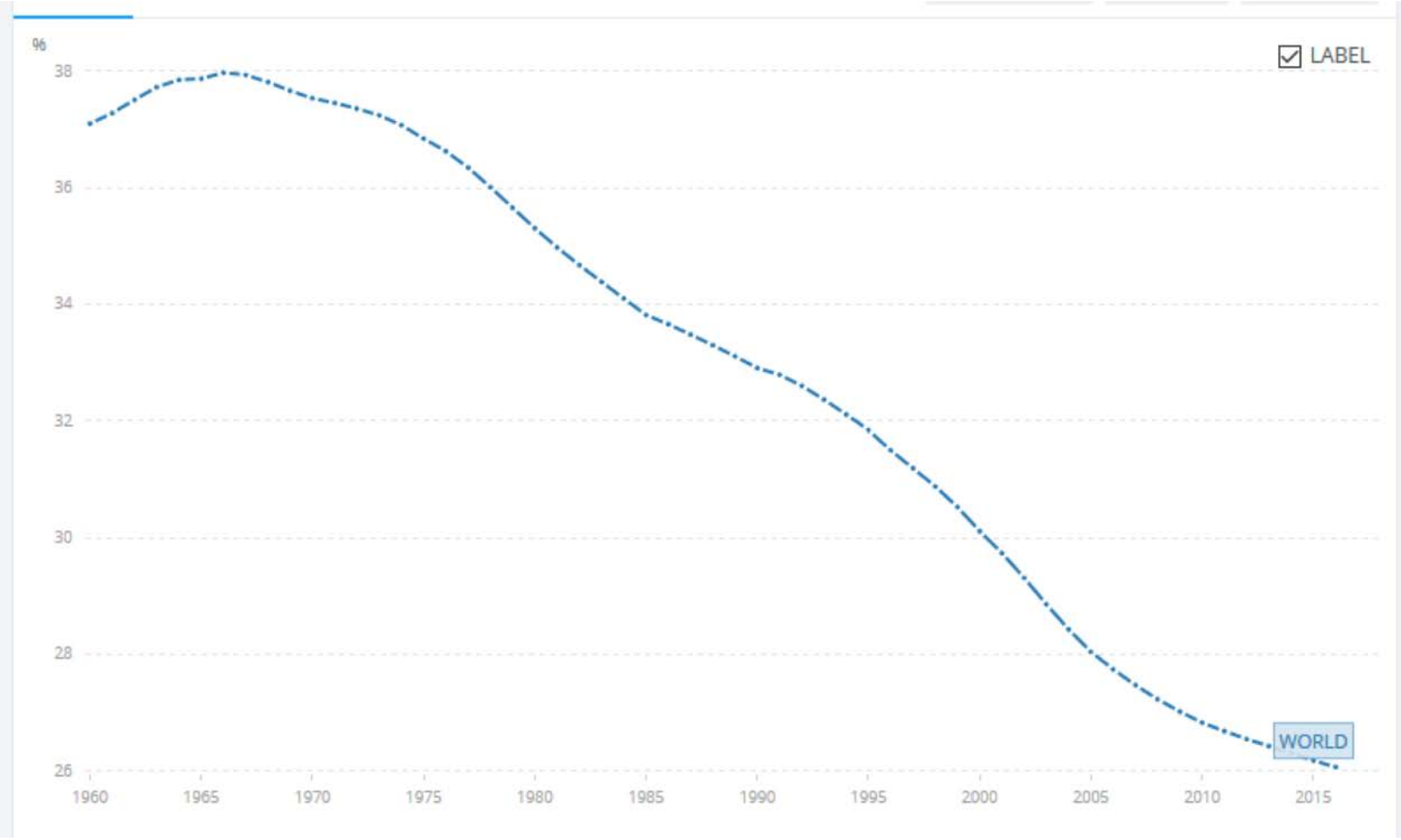
% of total World population > 65 years old



[1] The World Bank https://data.worldbank.org

THE WORLD: A AGING SOCIETY

% of total World population < 14 years old



[1] The World Bank https://data.worldbank.org

BETWEEN NEEDS AND SOLUTIONS

- Prevention
  - Continuous training required
  - Subjective training estimation
- Monitoring
  - Logistics problems
  - Privacy concerns
  - Subjective needs estimation
- Support and care
  - Emotional distress
  - Subjective needs estimation

TECHNICAL

EMOTIONAL

ECONOMICAL

PROBLEMS