Social participatory design of technologies for the Aging Society

Note: The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.

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


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
• Prevention
  – Continuous training required
  – Subjective training estimation

• Monitoring
  – Logistics problems
  – Privacy concerns
  – Subjective needs estimation

• Support and care
  – Emotional distress
  – Subjective needs estimation
DIFFERENT NEEDS MEET TECHNOLOGY

Prevention

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

Monitoring

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

Physical and Physiological support

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

Psychological support

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

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

WHY?
USER-CENTERED ISSUES

<table>
<thead>
<tr>
<th>Table 1 – Barriers to HIT adoption in the elderly.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarity and access</td>
</tr>
<tr>
<td>Need for assistance</td>
</tr>
<tr>
<td>Trust</td>
</tr>
<tr>
<td>Privacy issues</td>
</tr>
<tr>
<td>Design issues</td>
</tr>
<tr>
<td>Physical issues such as</td>
</tr>
<tr>
<td>Sight loss</td>
</tr>
<tr>
<td>Hearing loss</td>
</tr>
<tr>
<td>Decreased kinesthetic ability</td>
</tr>
<tr>
<td>Cognitive, navigation, and memory issues</td>
</tr>
</tbody>
</table>

E. M. Rogers’s Bell curve

Development

Acceptance

Wide distribution


TECHNOLOGY TO SUPPORT AGING

Development
Assessment

Acceptance
Adoption

Low acceptance
TECHNOLOGY TO SUPPORT AGING

- Development
- Assessment
- Acceptance
- Adoption

WHY?
COMMUNITY-CENTERED ISSUES

Several stakeholders

- Development
- Assessment
- Acceptance
- Adoption
- Wide distribution

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

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
• Mobility decline with age
  – Inconstant slope (faster if disease or accident)\(^1\)
  – Correlated with cognitive abilities

• 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

\(^1\) Including but not limited to mobility

* Require nursing care under a certain level

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

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

**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**

---

TEMPORAL GAIT PARAMETERS

- Stride time
- Stance phase duration
- Swing phase duration
- Double stance phase duration

\[
\begin{align*}
IC_{i+1} - IC_i \\
TC_i - IC_i \\
IC_{i+1} - TC_i \\
TC_{l/r} - IC_{r/l}
\end{align*}
\]

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)
• Algorithms based on angular velocity of shanks or feet have been tested under:
  – Parkinson's disease (PD)
    • Shank-based  TC: $-8.7 \pm 12.5$ms  IC $-2.9 \pm 26.8$ms
  – Spinal injury
    • Shank-based  TC: $-53 \pm 11$ms  IC $61 \pm 10$ms
    • Foot-based  TC: $-17 \pm 18$ms  IC $27 \pm 28$ms
  – 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 delay 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”
• Walking is the most popular training\textsuperscript{[3]}
  \begin{itemize}
    \item KXM is not trained
    \item Unrecognized training insufficiency\textsuperscript{[4]}
  \end{itemize}

\textbf{MUSCLE TRAINING}

\begin{itemize}
  \item Enhance KXM training
  \item Visualize muscular activity
\end{itemize}

\textsuperscript{[3]} 総務省・平成24年統計からみた我が国の高齢者
LONG TERM OBJECTIVE

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

Typical Application:
Healthy adult walk with training device for 30 minutes everyday.
# MUSCLE ACTIVITY ESTIMATION: STATE OF ART

<table>
<thead>
<tr>
<th>Method</th>
<th>Merit</th>
<th>Limitation</th>
<th>IMU + GRF [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromyography (EMG)[1]</td>
<td>Direct measurement of muscular activity</td>
<td>Direct placement on skin</td>
<td>No work space limitation</td>
</tr>
<tr>
<td>Optical Motion Capture[2]</td>
<td>Measurement of whole body link model with high accuracy</td>
<td>Artifact on skin surface</td>
<td>Ground Reaction Force</td>
</tr>
</tbody>
</table>

**A simple muscular activity estimation is needed**

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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]

MATERIALS AND METHOD

Event detection

Angle detection

Stance, Swing

Torque Estimation

Evaluation

EMG Process

Accelerometer (LIS331DLH)

- Axis: 3-axis
- Range: ±2/±4/±8 [G]
- Resolution: 1/2/3.9[mG/digit]
- Bandwidth: 25/50/500[Hz]

Gyroscope (LYPR540AH)

- Axis: 3-axis
- Range: ±400/±1600 [deg/s]
- Resolution: 3.2/0.8[mV/dps]
- Bandwidth: 140[Hz]

Magnetometer (HMC5843)

- Axis: 3-axis
- Range: ±4 [Gauss]
- Resolution: 12 [bit]
- Bandwidth: 50[Hz]
GAIT EVENTS DETECTION

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

KNEE ANGLE DETECTION

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

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

\[ \theta_i = \arccos(2(q_1q_2 - q_3q_4)) \quad (3) \]

\[
    C_n^b(q) = \begin{bmatrix}
    q_1^2 - q_2^2 - q_3^2 + q_4^2 & 2(q_1q_2 + q_3q_4) & 2(q_1q_3 + q_2q_4) \\
    2(q_1q_2 - q_3q_4) & -q_1^2 + q_2^2 - q_3^2 + q_4^2 & 2(q_2q_3 + q_1q_4) \\
    2(q_1q_3 - q_2q_4) & 2(q_2q_3 - q_1q_4) & -q_1^2 - q_2^2 + q_3^2 + q_4^2
    \end{bmatrix} \quad (2)
\]
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 11 steps × 2
  – Normal walk 5m × 2
  – Fast walk 5m × 2
  – Maximum Voluntary Contraction (MVC)
RESULTS: MUSCLE ACTIVITY ESTIMATION

Significant difference for different training level

Steel-Dwass test
** : p < 0.01
SMART KNEE EXTENSOR TRAINER

<table>
<thead>
<tr>
<th>Parts*</th>
<th>Weight [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkage Mechanism</td>
<td>796</td>
</tr>
<tr>
<td>Coupling</td>
<td>349</td>
</tr>
<tr>
<td>Fitting bands</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>1231</td>
</tr>
</tbody>
</table>

*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

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

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

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?

① AHA Trainer

② BlessBot
Culturally adaptive

(German)

(Japanese)

③ MusicBot

Session Recording...
Hans Reuter
• Sad face
• Slow moves
• Low physiological data
Paul Weber
• Happy face
• Confident attitude
• Physiological parameters in range ...

...
Several stakeholders

**CAUSE**

- Development
- Acceptance
- Wide distribution

**Stakeholders:**
- Scientists
- Engineers
- Technologists
- Designers
- Individuals
- HC professionals
- Families
- Economists
- Authorities
- End users
- HC facilities
- Govt policies

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

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

• 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
THANK YOU VERY MUCH FOR YOUR ATTENTION!
MY RESEARCH: STUDY OF AHA NEEDS

- People requiring care: 5 million [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
[3] 総務省・平成24年統計からみた我が国の高齢者
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

DEVELOPMENT OF TECHNOLOGY FOR AHA

Event detection
- \( \alpha, \omega \)
- Angle detection

Torque Estimation
- \( \theta \)
- \( T_{knee} \)

Evaluation

EMG Process

EMG

Accelerometer (LIS331DLH)
- Axis: 3-axis
- Range: \( \pm 2/\pm 4/\pm 8 \) [G]
- Resolution: \( 1/2/3.9 \) [mG/digit]
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DISCUSSION

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

<table>
<thead>
<tr>
<th>Threshold Nms/mkg</th>
<th>Causing Sarcopenia</th>
<th>Endurance</th>
<th>Endurance</th>
<th>Hypertrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.8 ~ 32.7</td>
<td></td>
<td></td>
<td></td>
<td>42.9 ~ 44.3</td>
</tr>
<tr>
<td>Estimation accuracy %</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Consideration of body parameters will improve the accuracy
Sweden, Japan: % of population > 65 years old

% of total World population > 65 years old

% of total World population < 14 years old

• Prevention
  – Continuous training required
  – Subjective training estimation

• Monitoring
  – Logistics problems
  – Privacy concerns
  – Subjective needs estimation

• Support and care
  – Emotional distress
  – Subjective needs estimation