COI WEARABLE SENSORS

BERNARD GRUNDLEHNER
RUBEN DE FRANCISCO
CHRIS VAN HOOF
Large track record
25+ ISSCC publications in bio-medical ICs
MULTI SENSOR IC MIXED-SIGNAL PLATFORM

imec MUSEIC
Industries smallest and most power efficient sensor hub

Sensors in Information out

LOW POWER | HIGHLY MINIATURIZED | MEDICAL GRADE
GENERIC HARDWARE PLATFORMS FOR MULTISENSOR APPLICATIONS

BIO-IMPEDANCE
POSTURE
ACTIVITY
HEART RATE
HEART RATE VARIABILITY
PHOTOPLETHYSMOGRAPHY
INTEGRATION INTO DEDICATED FORM FACTORS, SUCH AS HEALTH PATCH
VALIDATED IN CLINICAL PILOT STUDIES
The Center of Innovation (COI) Program

Three visions of COI STREAM (The society in 10 years ahead that we want to create)

Vision 1
Secure sustainability as a country advanced in its aging population and declining birth rate
Smart Life Care, Ageless Society
Key concepts (function)
Medical health, Mental health, Motivation, Sports, Food, Ties
⇒ Realization of happiness

Vision 2
Create a living environment with a high Quality of life as a prosperous and reputable country
Smart Japan
Key concepts (function)
Intuition, Active thinking, Serendipity, Six senses
⇒ Innovative thinking method

Vision 3
Establish a sustainable society with vitality
Active Sustainability
Key concepts (function)
(Personalization, Resilience, Sustainability, Functionalization, Flexibility) - Waste
⇒ Development of a durable town for centuries
The Center of Innovation (COI) Program

Three visions of COI STREAM (The society in 10 years ahead that we want to create)

**Vision 1**
Secure sustainability as a country advanced in its aging population and declining birth rate
- **Smart Life Care, Ageless Society**
  - Key concepts (function)
    - Medical health, Mental health, Motivation, Sports, Food, Ties
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**Vision 2**
Create a living environment with a high Quality of life as a prosperous and reputable country
- **Smart Japan**
  - Key concepts (function)
    - (intuition)ing thinking, Active thinking, Serendipity, Six senses
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**Vision 3**
Establish a sustainable society with vitality
- **Active Sustainability**
  - Key concepts (function)
    - (Personalization, Resilience, Sustainability, Functionalization, Flexibility) - Waste
  - ⇒ Development of a durable town for centuries

Institutions:
- Hokkaido Univ.
- Hirosaki Univ.
- Tohoku Univ.
- Univ. Tokyo
- Ritsumeikan
- Kyoto Univ.
- Osaka Univ.
- Hiroshima Univ.
- Tokyo Inst Tech
- Tokyo Univ. Arts
- Yamagata Univ.
- Keio Univ.
- Kanazawa Inst Tech
- Univ. Tokyo
- Shinsyu Univ.
- Nagoya Univ.
- Kyusyu Univ.
“The Self-Empowerment Society where people can fulfill their potential”

**Happy Society**
Where each and every Super Nippon-jin can maximize their potential and enjoy their life to the fullest

Super Nippon-jin represents those who can always fulfill their potential

Brain networks
- Further activation
- Visualization and activation
- Evaluation of activation level
- Provision of activation method

**Brain management**
Status Detection
- Exercise for brain activation
- Stress detection
- Direct stimuli
- Brain music

**Community networks**
- Provision of activation method

**Activation scene**
Create a living space where stress will be eliminated and motivation be encouraged

**Education**
- Activation by group with the communication quality improved
- Business/Community
- Adulthood
  - School Education
  - Sports
  - parent-child communication
- Childhood
  - Sports
  - Sympathetic Robot

**Health**
- Exercise for brain activation
- Stress detection
- Direct stimuli
- Brain music

**Activation scene**
- Before
- At school
- After
- In motion
- At home

**Public scene**
- private scene

**Brain networks**
Further activation of brain by eliminating stress

**Activation scene**
Create a living space where stress will be eliminated and motivation be encouraged
<table>
<thead>
<tr>
<th>Grouping</th>
<th>Development theme(14)</th>
<th>Partners(40)</th>
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<tbody>
<tr>
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# Osaka Univ. COI theme and our partners

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<th>Companies (26)</th>
<th>Panasonic (leading company), imec International, Hitachi, DAIKIN, YAMAHA, SYOWA DENKO, SEMEDAIN, KANEKA, MEKTRON, MEDHINET, Quantum Biosystems, ORGANO, etc</th>
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3 DEVICES FOR 3 FIELDS OF APPLICATION

1) **Wristband** for measuring **GSR** (Galvanic Skin Response) and **skin temperature** reflecting autonomic nervous system responses, emotional responses

2) **ECG patch** for very precise detection of **heart beats** heart rate variability reflecting **ANS modulation**, emotional responses, **sleep**

3) Easy to use **EEG headset** for measuring **brain waves** measuring sleep quality, emotions and responses of the central nervous system to auditory and visual stimulation
3 DEVICES FOR 3 FIELDS OF APPLICATION

1) **Wristband** for measuring **GSR** (Galvanic Skin Response) and **skin temperature**
   - > 7 days autonomy, comfortable to wear, large dynamic range

2) **ECG patch** for very precise detection of **heart beats**
   - > 7 days autonomy, comfortable for wide range of skin types

3) Easy to use **EEG headset** for measuring **brain waves**
   - *Easy to put on, medical grade signal quality*

- **Synchronized acquisition of all devices**
- **Smart phone interface for monitoring data and controlling devices**
3 DEVICES FOR 3 FIELDS OF APPLICATION

- **Brain music**
  - EEG headset
  - GSR band
  - ECG patch

- **Psychiatry**
  - EEG headset
  - GSR band
  - ECG patch

- **Sleep research**
  - ECG patch
  - GSR band
3 DEVICES FOR 3 FIELDS OF APPLICATION

EGG headset  ECG patch  GSR wristband

can be controlled from an Android smart phone, tablet P
GSR Wristband
Accurate recording of GSR, 3D acceleration and skin temperature for 7 **days** without charging.

**Use case: managing depression**

- **Diary:**
  - Patient is sent home with sensor for 1 week or longer
  - Mood changes are logged

- **Treatment:**
  - Finding correlates between life style and mood swings

From prof. Kikuchi, Kanazawa Univ.
Enabling to measure human activities, skin temperature, skin conductance for long days (10 days)

GSR Wristband
Accurate recording of GSR, 3D acceleration and skin temperature for 7 days without charging.

From prof. Kikuchi, Kanazawa Univ.
Human activities evaluation by GSR frequency analyses (frequency analyses per 5 seconds)

Comparison among various works

Comparison among vehicles

Shinkansen (700series)
Limited express Shirasagi
City bus

Quite active around 2Hz!
Continuous acceleration measurement for 9 days

Activities are found to be around 2Hz

Data analyses of 9 days continuous acceleration measurement

From prof. Kikuchi, Kanazawa Univ.

Divided per 6 min period

FFT per 6 min → extraction of 2Hz power

Power value

Change in 2Hz
Time series extraction of 9 days continuous 2Hz power

From prof. Kikuchi, Kanazawa Univ.

Data analyses of 9 days continuous acceleration measurement

Frequency distribution

FFT per 6 min $\rightarrow$ extraction of 2Hz power

Power value

Change in 2Hz

Sleeping time
Clearly seen!
As for distribution of occurrence frequency of exercise intensity per day, strong linear relation can be seen through 9 days by logarithmic transformation. From now on, this analysis (including body temperature, skin conductance) will be considered whether can be handled as the objective index of depression disease.
Thank you for attention