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Indoor Environment Control Method for Improving Well-Being using Human Thermal Stress Estimated by Yuragi Learning

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Background

- Individual's good work-life balance are being recommended [1]
  - Many changes in work style can be burdensome for workers[2]
- There is still room to consider ways of working
  - Increasing productivity while taking into account personal well-being [3]
- Biometric information can estimate stress state[6]
  - Using skin potential activity, skin temperature, and pulse wave

[1] "Abenomics: For future growth, for future generations, and for a future japan (Online available).
[2] D. E. Guest, "Human resource management and employee well-being: Towards a new analytic framework," Human resource management journal, 2017.
[3] A. Sakuraya, et al., "Job crafting, work engagement, and psychological distress among japanese employees: A cross-sectional study," BioPsychoSocial medicine, 2017.
[6] P. Schmidt, et al., "Introducing wesad, a multimodal dataset for wearable stress and affect detection," in Proc. ACM ICMI, 2018.

Purpose and Problems

- Purpose
  - Estimating the stress state of each individual from human biological information
  - Controlling the indoor environment based on human stress
    - Individual can stay comfortably

Image of comfortable room

- Problems
  - The biological information from wearable sensors contains noise
  - Stress affects biometric information differently for each individual
    - Using Yuragi learning to solve these problems

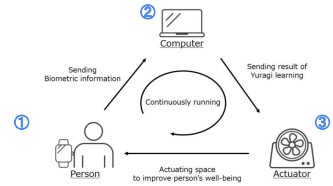
Even in the same indoor environment

Changed modality		Changed modality
• Electrodermal activity : HIGH • Skin temperature : LOW	Subject A Subject B	• Electrodermal activity : LOW • Skin temperature : HIGH

Image of Stress affects biometric information differently person to person

Proposal

- Realizing well-being space by 3 steps
  1. Sense various biometric information using biometric sensors
  2. Estimate a person's psychological state from the biometric information
  3. Intervene indoor space by controlling actuators
     - To relieve the stress state
- We implement this system and conduct experiments



Overview of system

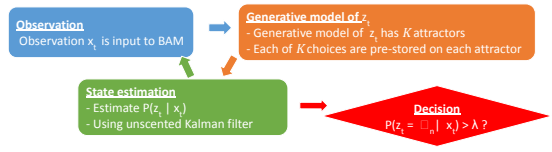
Wearable Stress and Affect Detection (WESAD)[6]

- Biometric information can estimate human emotional state
  - Various biometric information from 15 subjects
    - Blood volume pulse (BVP), Electrocardiogram (ECG), Electrodermal activity (EDA), Electromyogram (EMG), Respiration (RESP), Skin temperature (TMP), and 3-axis accelerometer (ACC)
  - Their self-reported is used as emotional-state label
    - Neutral, Stress, Amusement
- They achieved high accuracy in estimating psychological states
  - Using machine learning methods on these data
  - Decision trees, Random forests, AdaBoost, Linear discriminant analysis, K-nearest neighbor methods
- Our research use as reference this study
  - Our research uses various biometric information too
  - Our research uses Yuragi learning[7] for estimating stress state

[7] M. Murata and K. Leibnitz, Fluctuation-Induced Network Control and Learning: Applying the Yuragi Principle of Brain and Biological Systems. Springer, 2021.

Bayesian attractor model (BAM)

- BAM models the decision process that human brain makes
  - BAM decides which of choices the observed information corresponds to
    - This decision-making can be made even from noisy information

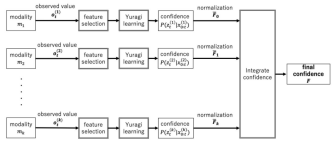


Overview of BAM

- Decisions are made according to confidence level
  - Confidence level means that how z_t is close to one of the attractors $\square_n$
  - Adopt Attractor whose confidence level exceeds the threshold λ
    - This allows decisions to be made with fewer errors for noisy observations

Multimodal recognition based on Yuragi learning

- Using BAM for decision making machine learning methods
  - Our research group has succeeded in various applications [7]
  - Can be run on relatively small systems
- Composed of frameworks that use BAM
  - Input observed information (preprocessing)
  - Set attractor (training)
  - Make decision
- In this study, integrating multiple biometric outputs



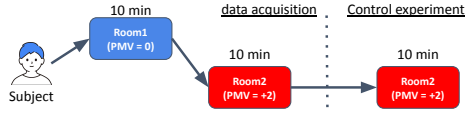
Overview of Estimating

Experimental setup

- Two rooms were set up as experimental environments
  - Indoor environment is set based on PMV[14]
    - Comfortable room was set as PMV = 0 (20℃, 40% humidity)
    - Uncomfortable room was set as PMV = +2 (30℃, 70% humidity)

Experiment Room

- Experimental steps
  - Acquisition of tain data (10min * 2)
  - Actuator-control experiment (10min)
    - Estimated subject's state is checked every 10 seconds
    - Actuator changes a room environment according to this state



Experiment flow

[14] "ISO 7730:2005 (Online available).

Devices

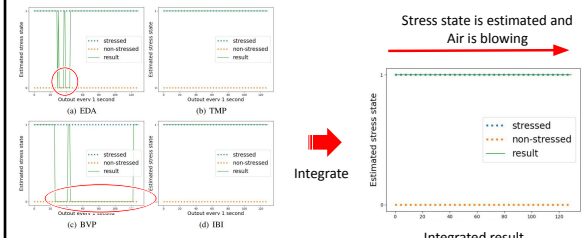
- Empatica E4 wristband [9]
  - It used for acquiring ACC, BVP, EDA, IBI, TMP
- Laptop computer
  - Installs a streaming server which receives biometric information
    - Connected to the E4 wristband via Bluetooth
  - Conducts Yuragi learning
  - Sends control commands to an actuator by the estimated result
- Daikin assisted circulator [10]
  - The circulator is connected to a Raspberry Pi 3 model B (PI3)
    - its operation can be changed by serial commands sent from the PI3
    - Blowing wind when stress state is estimated

E4 wristband and assisted circulator

[9] "E4 wristband," https://www.empatica.com/en-int/research/e4/, (Accessed on Nov. 1, 2023).
[10] "Daikin assisted circulator," https://launch.ac.daikin.co.jp/onlineshop/ detail/03, (Accessed on Nov. 1, 2023).

Result

- Stress state are estimated and control execution is confirmed
  - Green line represents the estimated state at each time step
  - Improved accuracy by combining multiple biometric data
  - In this experiment, the control always runs



Result of Estimation

Conclusion

- We proposed a Yuragi Learning based stress estimation method
  - Integrating multiple types of biometric information
  - Experiments have shown that the system can operate corectry
- Future works
  - How to control the actuators to completely remove stress
    - Pursuit of adequacy of actuating methods
  - How to estimate and control them for different people at the same time
  - Another experiment senario
    - Control PMV by changing exercise
      - In this research we control PMV by temperature and humidity

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