Smart Home and Smart Appliance Control @NAIST-UBI in collaboration with Ausilia

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Measurement Instrumentation and Robotics MIRo Lab, UNITN
Assisted Unit for Simulating Independent LIving Activities

Ubiquitous Computing Systems Lab.

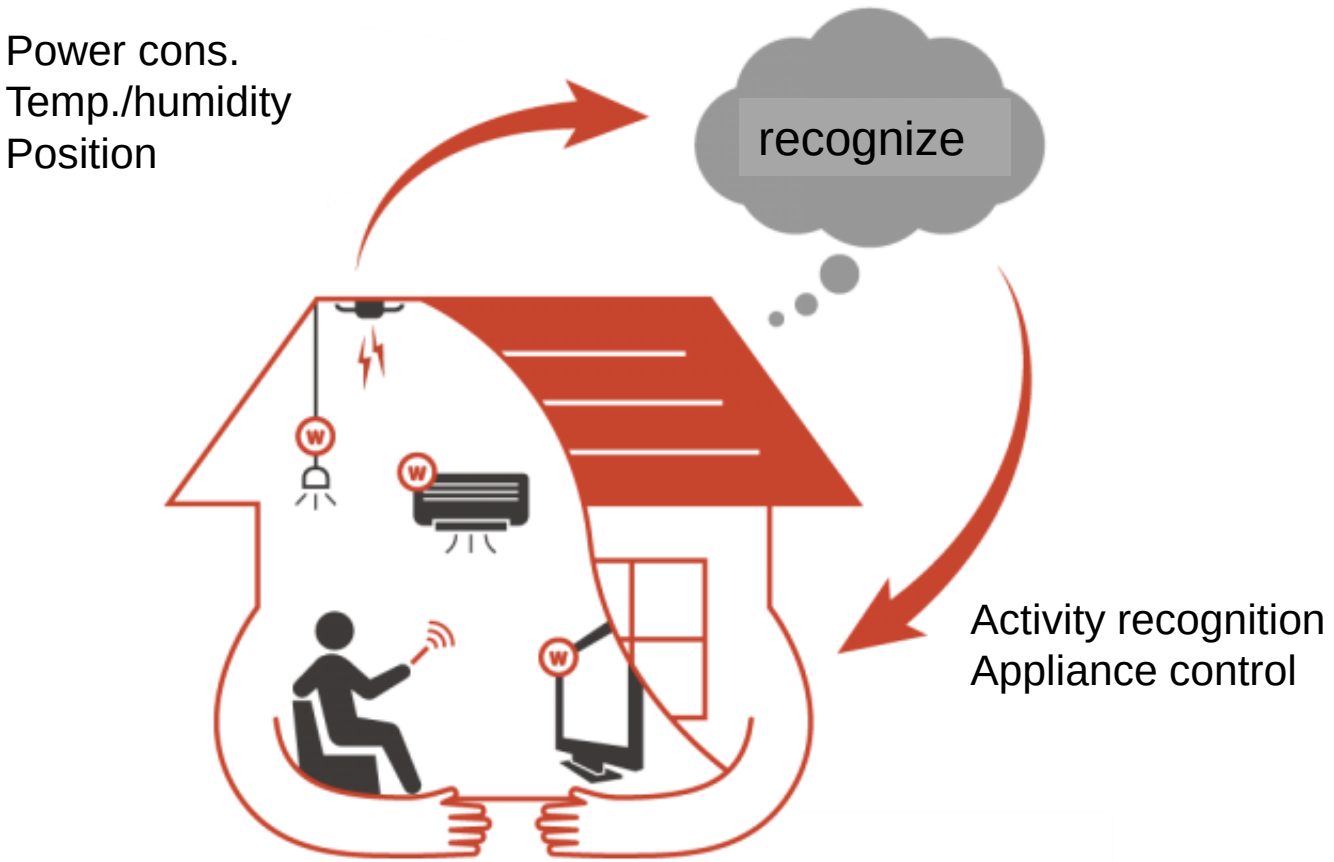
- Staffs: 5 faculty
  - Keiichi Yasumoto (Prof.), Yutaka Arakawa (Assoc.prof),
  - Hirohiko Suwa, Manato Fujimoto, Teruhiro Mizumoto (Assist.profs)





- 30 students (7 int'l.): 8 doctoral + 20 masters + 2 interns

http://ubi-lab.naist.jp/


Power cons.
Temp./humidity
Position
recognize
Activity recognition
Appliance control

Smart Home

Topics of Smart Home Group

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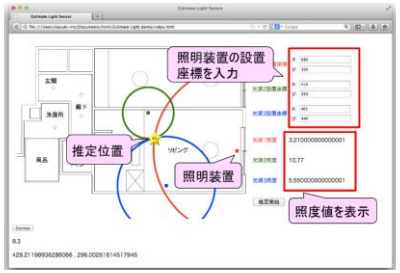
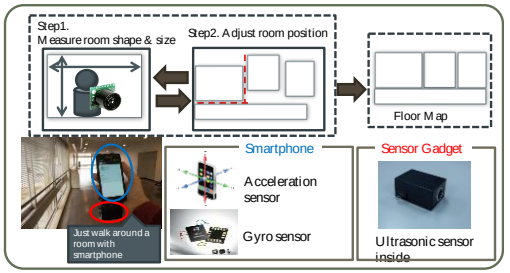
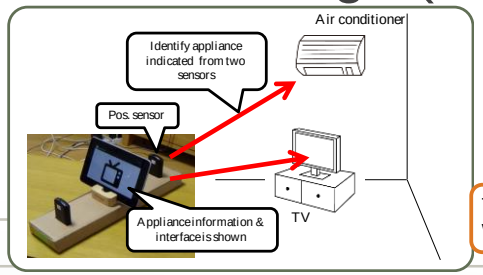
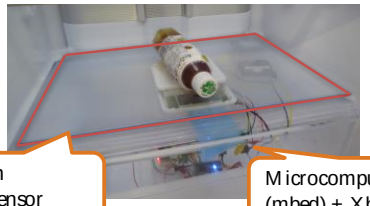
- **Sensing homes**
  - Indoor positioning
  - Floor plan creation



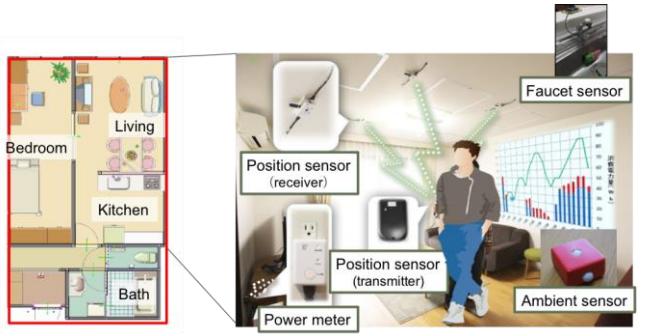


- **Smart Appliances Control**
  - Low-energy appliance operation
  - Intuitive remote controller
  - Smart fridge (food recognition)





- **Sensing human activities**
  - ADL (Activity of Daily Living) recognition
  - ADL prediction
  - Elderly monitoring

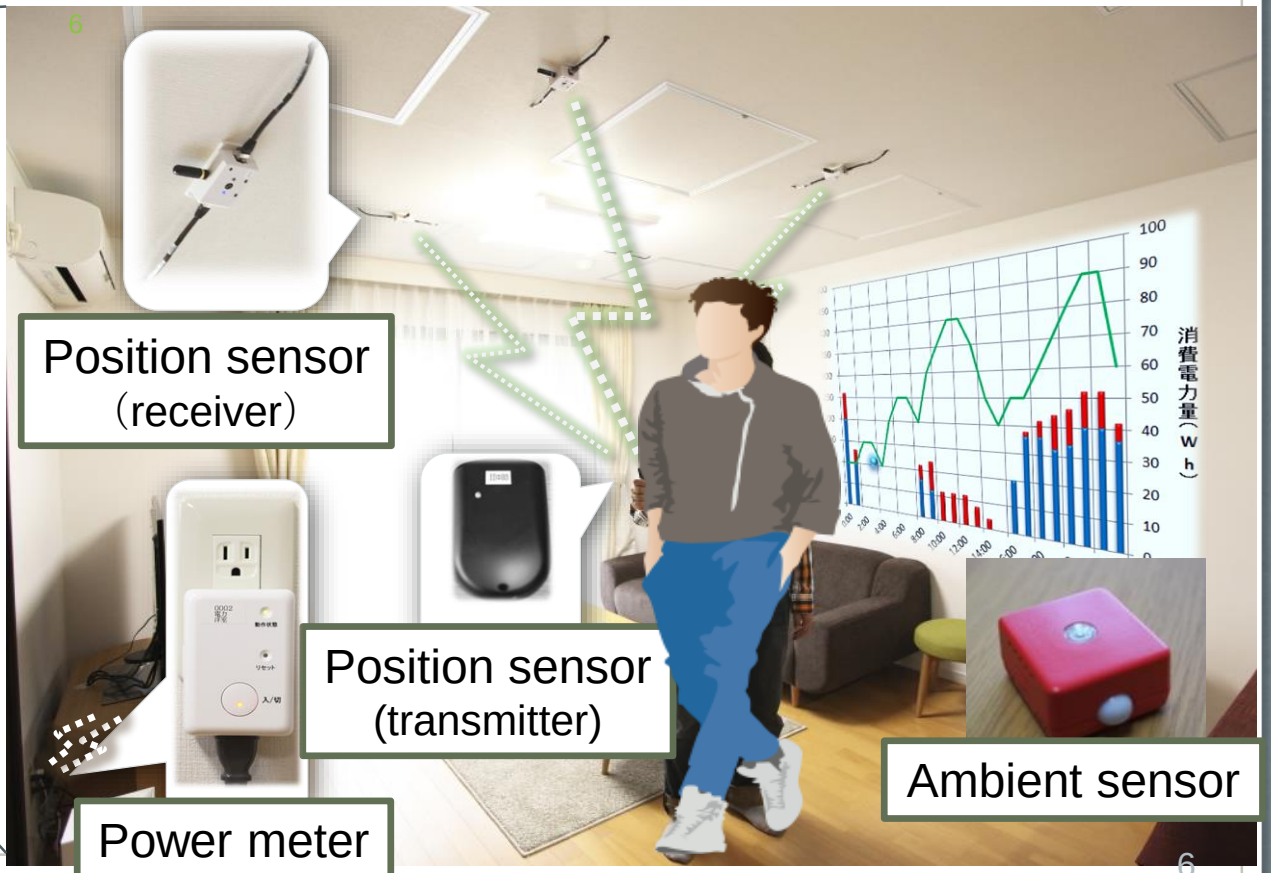


- **Life support (on going)**
  - Activity recommend./support
  - QoL measurement/monitoring

Sensing Human Activities in Smart Home in Collaboration (with MIRo Lab and AUSILIA)

Smart Home in NAIST

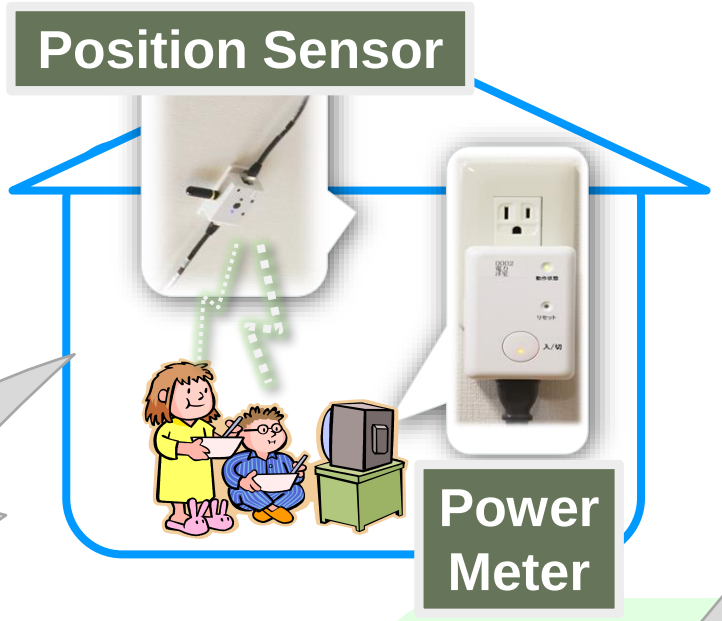
- 1 LDK, built in 2013
  - Collect data & develop methods for ADL recognition
  - Develop context-aware smart appliance control systems



Base Method for Activity Recognition

ECHONET Lite: Air conditioner, Ceiling light, Fridge, IH, TV, Air purifier

Motion sensors attached on the appliances



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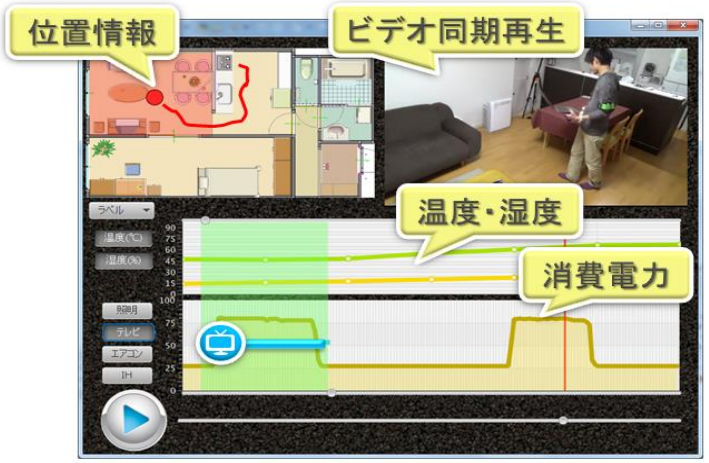
Activity Recognition

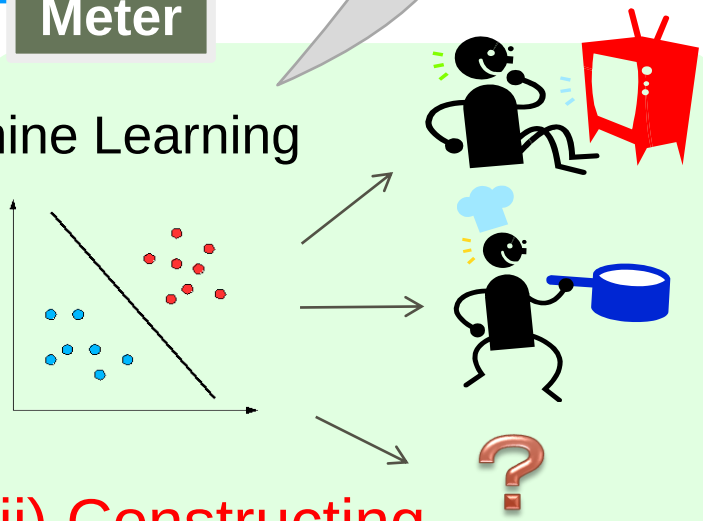
Sensor Data



(i) Labeling data

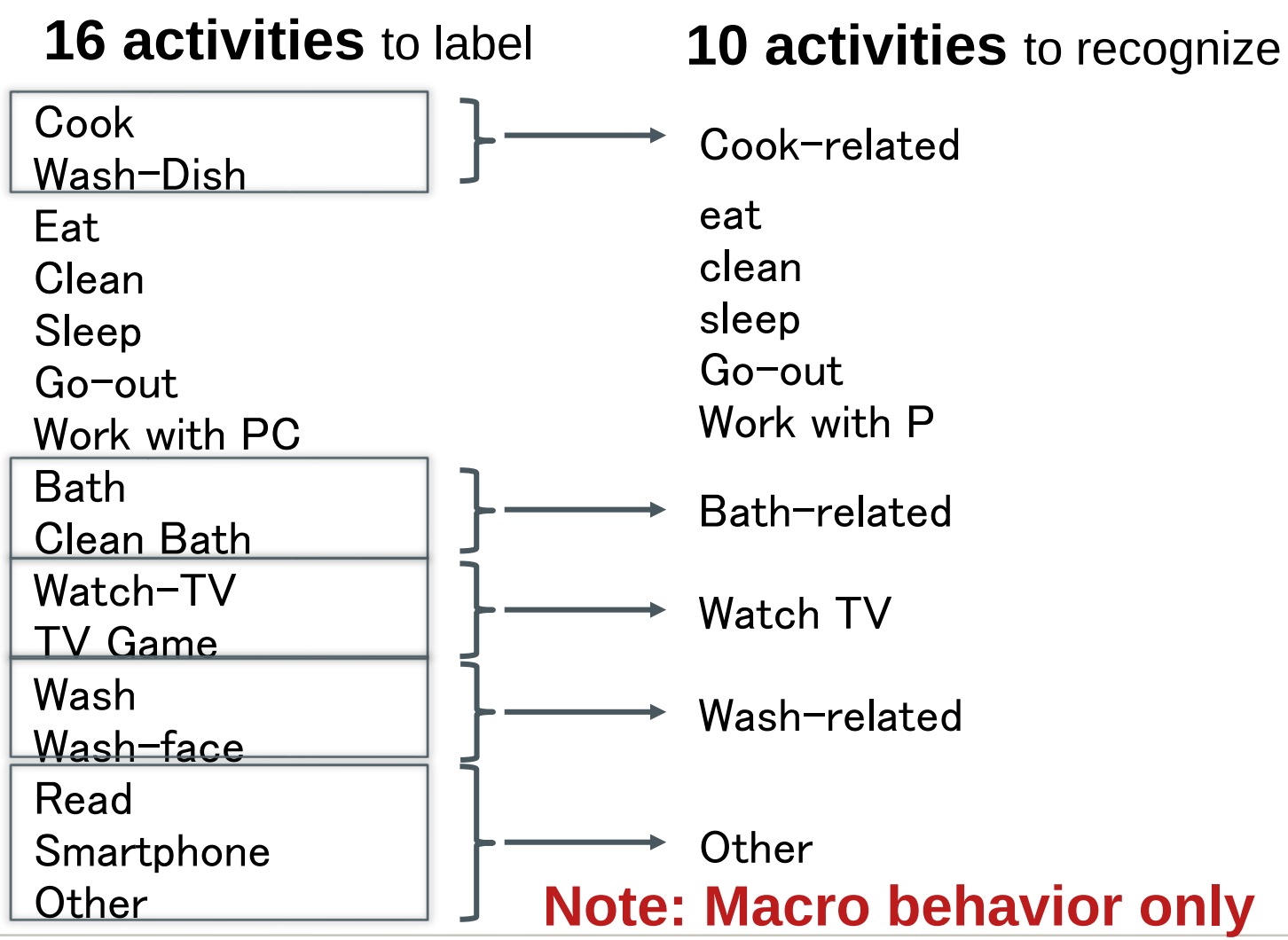
(ii) Extracting features

Machine Learning



(iii) Constructing classifier

Target Activities

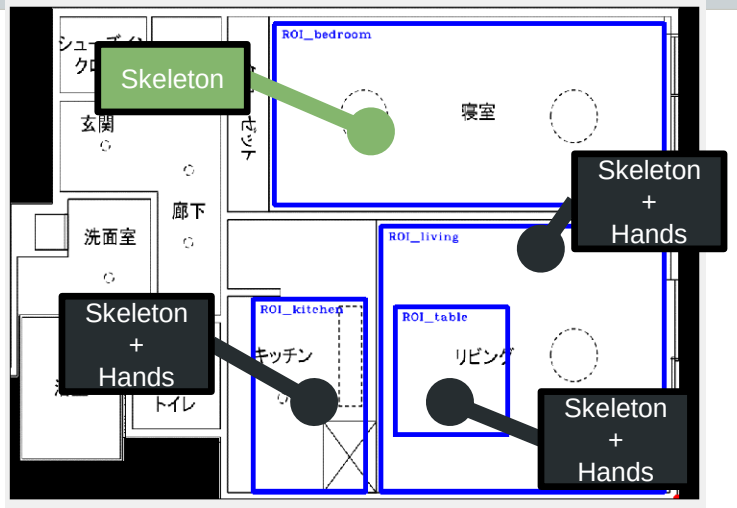


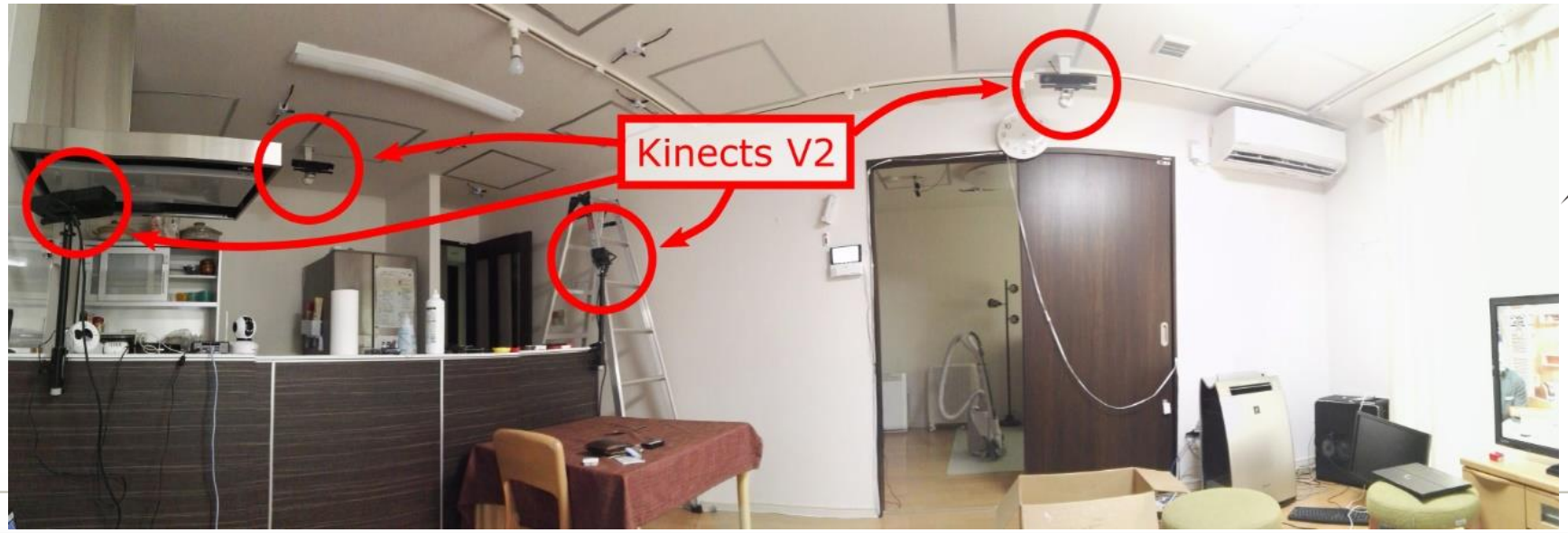
Micro behavior (atomic action recognition)

Development of techniques for recognition of micro behaviors, actions, for the domestic context.

<u>Requirement: to maintain the privacy level for the user.</u>

FIRST RESULT: deployment and improvement (at data analysis level) of the developed distributed 3D acquisition system.





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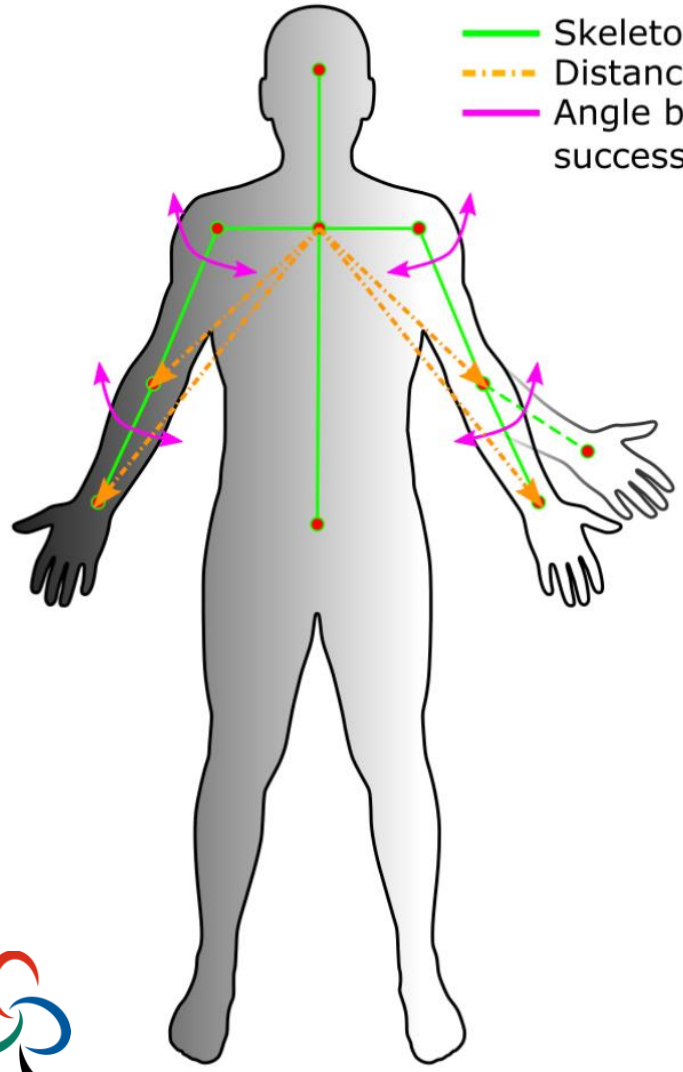
AUSILIA


Skeleton
Distance between nodes
Angle between
successive vectors in time

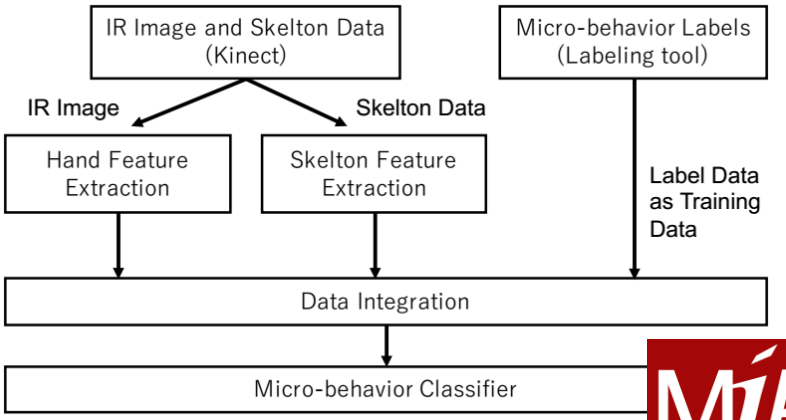
+

Kitchen Labels → actions to be recognized (desiderata)

1. PICKUP_tool
2. PICKUP/RETURN_foodstuff
3. PICKUP_seasoning
4. PREPROCESSING_cutting_slicing
5. MIXING
6. PREPROCESSING_pouring_powdering
7. HEATER_put_pan
8. HEATER_remove_pan
9. OVEN_put_dish
10. OVEN_remove_dish
11. TASTING_DRINKING
12. GARNISHING
13. WASHING

Achievements:

- **5 kinects were settled in the SMART-HOME**
- **Automatic device activation and data recording**
- **Definition of spatio-temporal features**
- **Training of a Random Forest classifier**
- **15 days of unsupervised data, about 200Gb of skeleton and hand images data.**
- **Control sequences of new subjects**
- **80-85% accuracy**



Objectives:

- **comparison in the classification accuracy between anonyms data Vs non anonymous data (picture, 3D)**
- **Automatic recipe identification**
- **Identification of action for assistive feedbacks.**

ADL recognition using ECHONET Lite appliances and motion sensors

	行動	precision	recall	f1_score	support
0	Other	0.845	0.973	0.905	1232
1	RelatedBath	0.988	0.955	0.971	178
2	Cleaning	0.976	0.976	0.976	41
3	Cooking	0.923	0.645	0.76	299
4	RelatedTV	0.844	0.974	0.904	644
5	PC	0.986	0.986	0.986	359
6	Sleeping	0.998	0.989	0.994	2278
7	GoOut	0.999	0.983	0.991	3672
8	WithTV	0	0	0	114
	avg/total	0.95	0.958	0.952	8817

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Smart Appliance Control

(context-aware appliance control)

Levels of smart appliance control

(imported definition)

Level 1 control with assistance:
Living space conditions (e.g., power consumption) are visualized, appliances are universally and/or intuitively controlled

Level 2 control with advice:
Favorable or unfavorable situation is detected and advice is given to residents

Level 3 conditional automation:
Specific contexts are recognized and appliances are automatically controlled

Level 4 high automation:
Partial human and environment contexts are **recognized/predicted** to control appliances for high comfort & energy-saving levels

Level 5 full automation:
Full human & environment contexts are recognized/predicted to control appliances for high comfort & energy-saving levels

(definition in autonomous driving)

Level 1 drive assistance:
Either steering or acceleration/ deceleration is assisted by the system Ex) automatic break

Level 2 partial automation:
Both steering and acceleration/ deceleration are assisted by the system

- Ex) ACC with steering assist

Level 3 conditional automation:
All driving tasks are automated under some conditions (human response needed)

Level 4 high automation:
All driving tasks are automated under some conditions (no need of human response)

Level 5 full automation:
All driving tasks are automated in all conditions (no need of human response)

Example of L1 appliance control

- DeepRemote: Intuitive Remote Controller using deep learning to recognize appliance for control

Takahashi et al.: DeepRemote: A Smart Remote Controller for Intuitive Control through Home Appliances Recognition by Deep Learning, ICMU2017

Example of L2 control

- Appliance control through smart agent

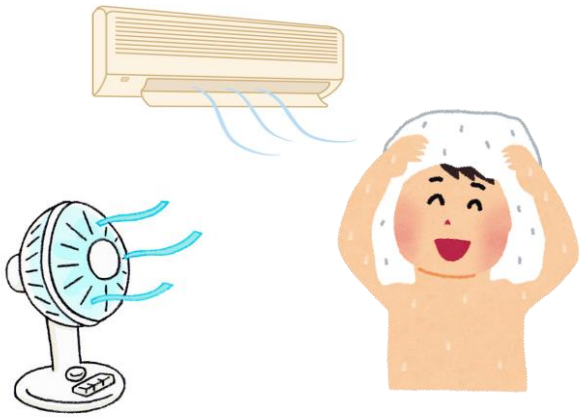
Level 3: Conditional automation

Goal:
recognize specific contexts and control appliances depending on the contexts

- Can be easily achieved if activity recognition is available

Example:

- No residents exists → turn off A/C, TV and others
- cooking → turn on exhaust fan, change air purifier's mode to strong
- After bath → change mode of A/C or cooling fan to strongest

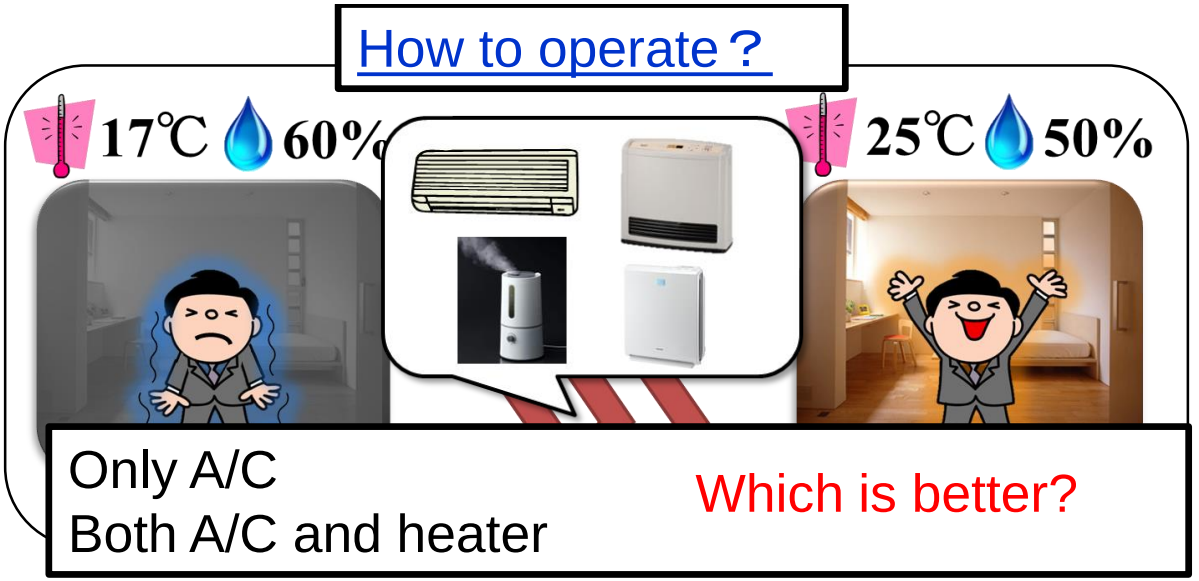


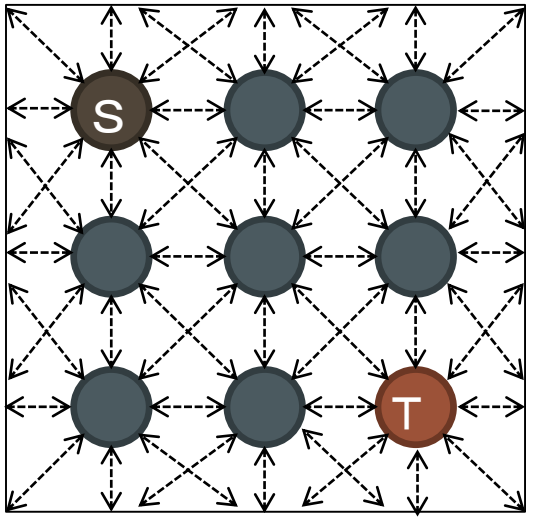
Level 4: high automation

Goal: achieve both energy-saving and high comfort through appliance automation

- Need to combine activity prediction and energy-saving appliance
  Ex) predict bedtime and cool/warm the bed room beforehand

Energy-saving appliance control problem & algorithm

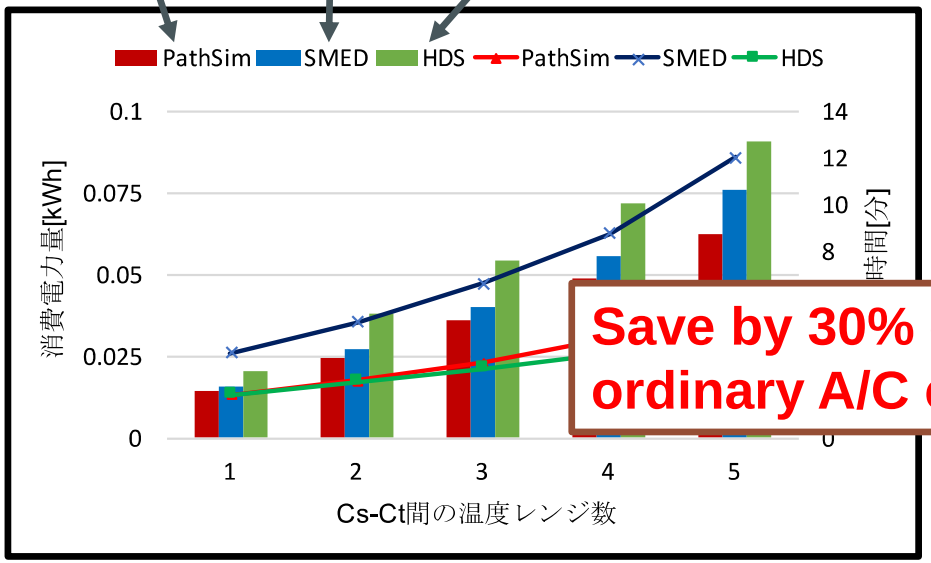




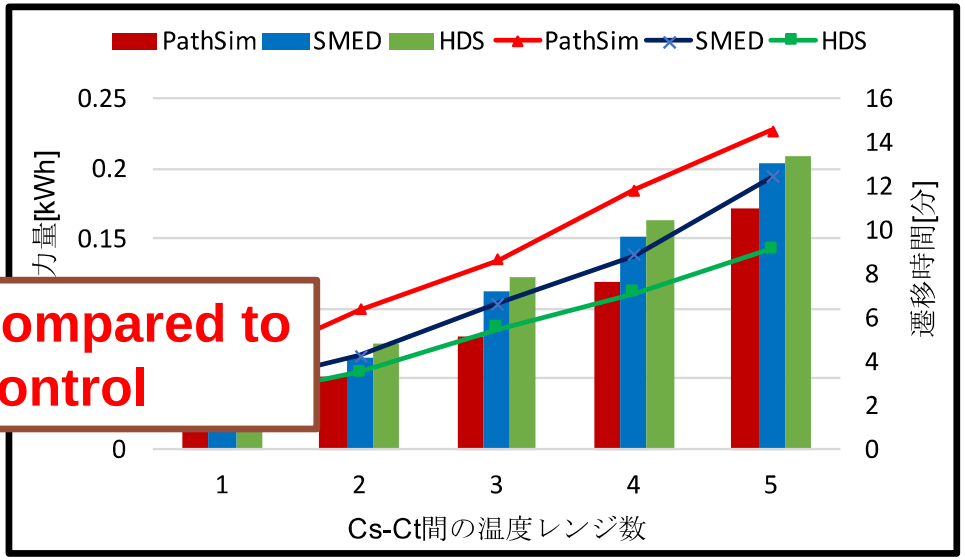
Derive optimal operation sequence by algorithm

Results

Proposed manual ordinary A/C control

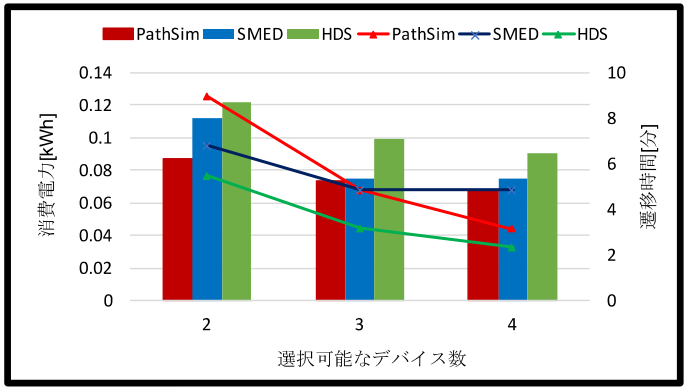


Save by 30% compared to ordinary A/C control



Summer (cooling) **Winter (warming)**

(appliances used: AirCon, heater, dehumidifier, humidifier)



Increasing devices improves energy-saving degree

Effect when increasing the **number of devices**

Level 5: Full automation

Challenges

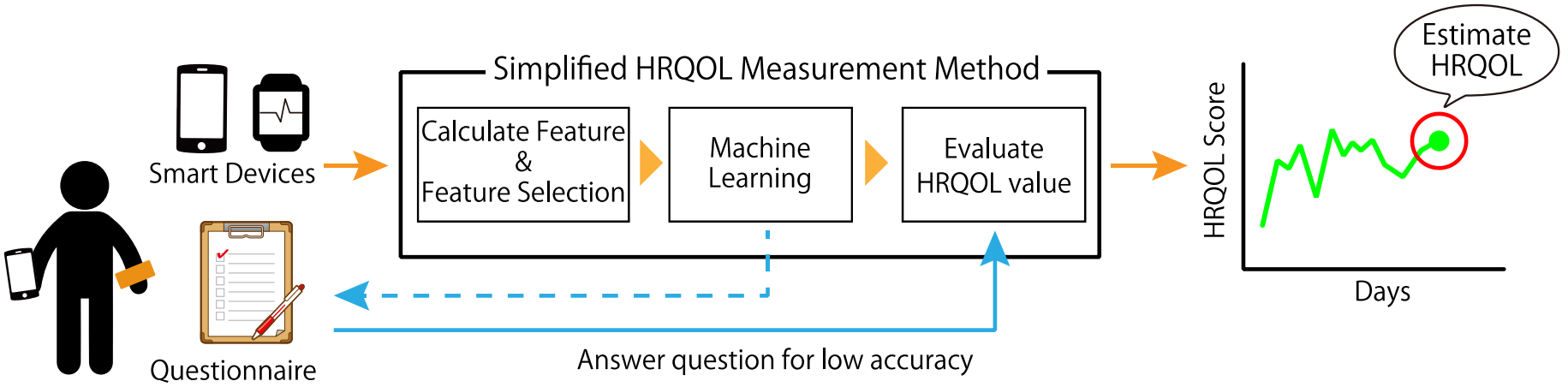
- Recognize current and future contexts of residents and environments
  - **Recognition and prediction of activities**, mental & physical conditions, preference, etc.
  - Recognition and prediction of living spaces parameters such as temperature, humidity, cleanness, illuminance)
- Predict and plan a pattern of appliance control that increases resident's comfort or happiness level
  - Measurement of comfort and QoL

Easy measurement of QoL

- Goal
  - Continuous QoL measurement
  - Mitigation of questionnaire load

Answering 26 questions every day is burdensome

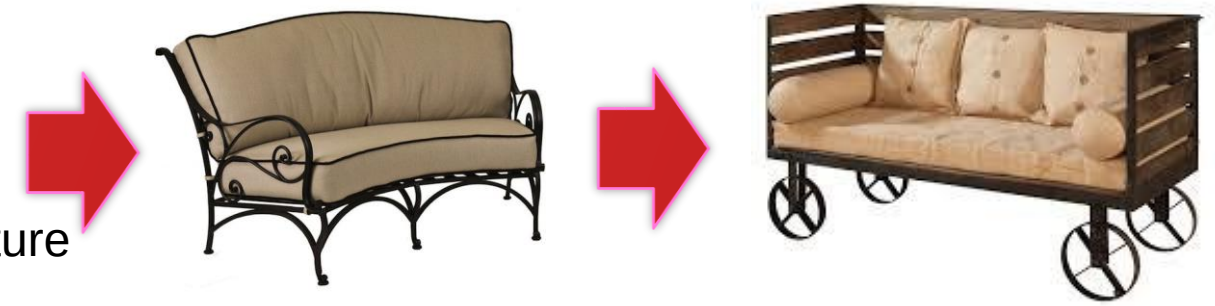
- Approach
  - Estimate the answer for each question of WHOQOL-BREF from sensor data



New Ideas

- **Development of smart Furnitures adaptable as a function of the user and his/her status**

INPUT:
- User identity (via image, smart phone ID)
- User activity recognition
- Sensors inside the furniture



Application examples:
- Table height adjustment as a function of posture
- Memo function (to highlight where things are, e.g. micro TAGS for localization)
- Motorized wall unit control
- Gesture control
- Illuminance systems control, projectors to illuminate/highlight and add content
- Cleaning status estimators
- Cooking power control for smart kitchens
- Safety systems for children

Thank you for your attention!