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Leading Innovation

Cloud Networked Robotics and Acceleration Based Sensing

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Tokyo, Japan

Robotics DTF, OMG

Dec. 11, 2012

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Mega Trends

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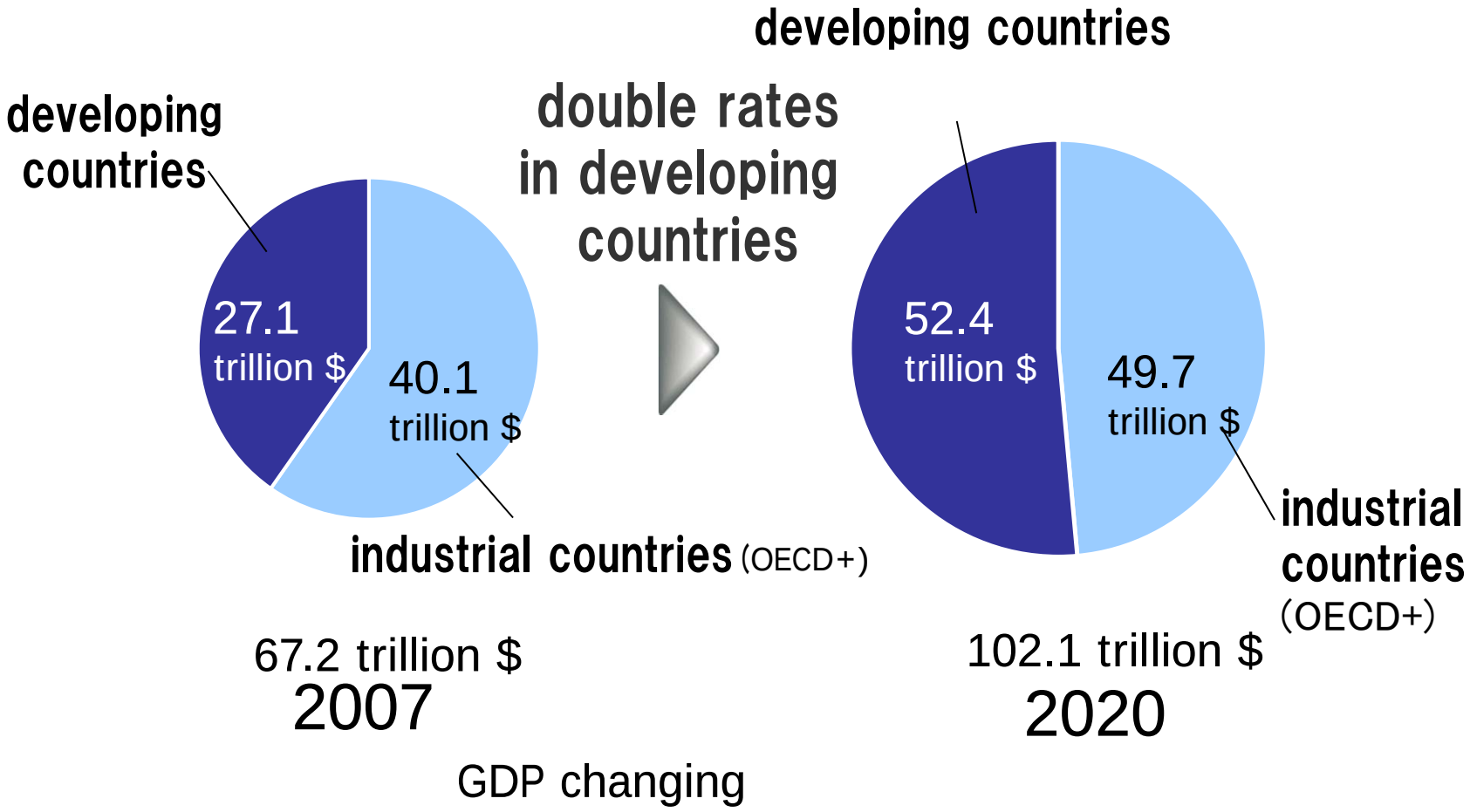
Economic developing center shifting to developing countries

Market center shifting to developing countries



(source: World Energy Outlook 2010

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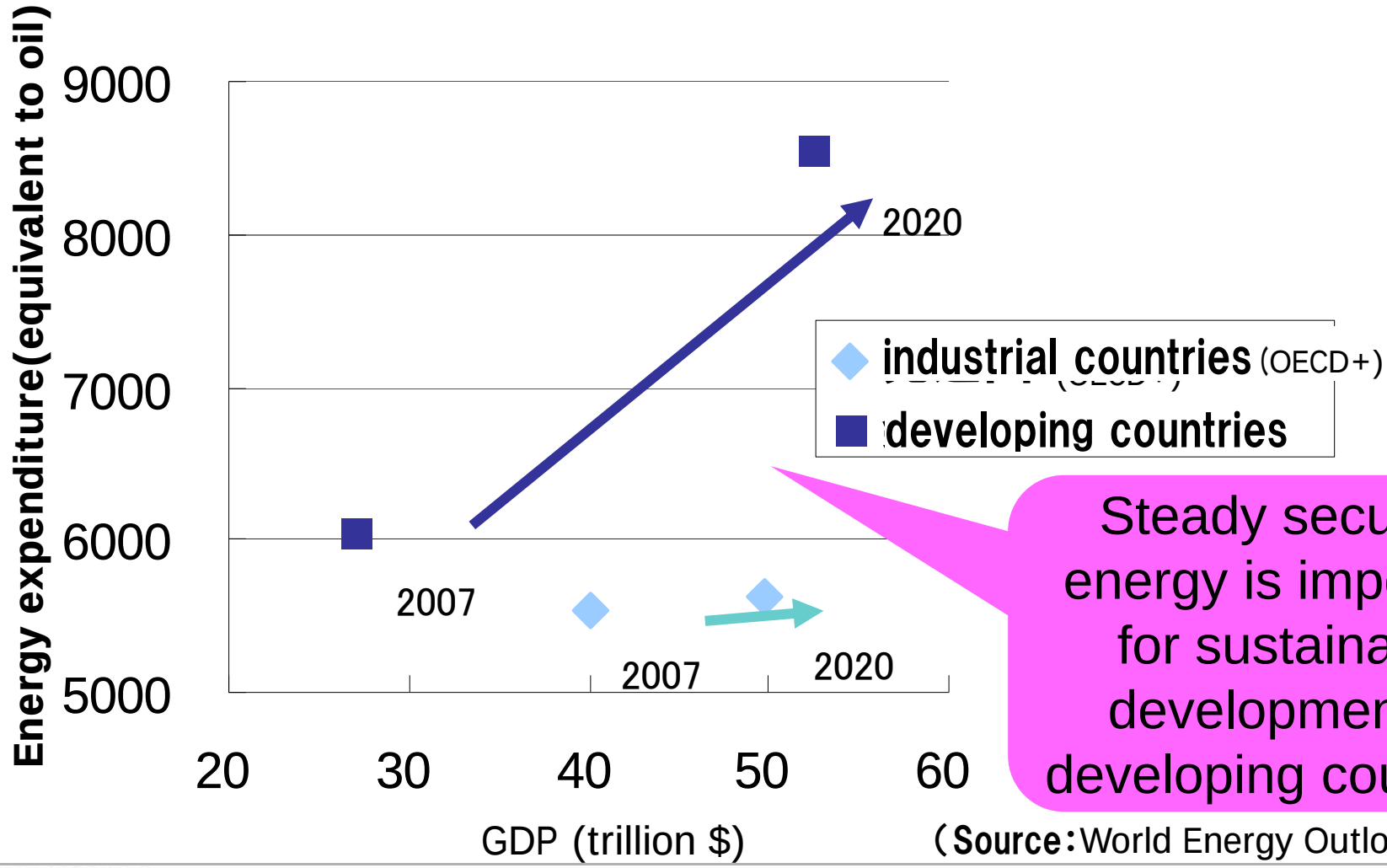
Energy expenditure center shifting to developing countries

Sharply-rising energy expenditure in developing countries



Steady securing energy is important for sustainable development of developing countries

（**Source**：World Energy Outlook 2010）

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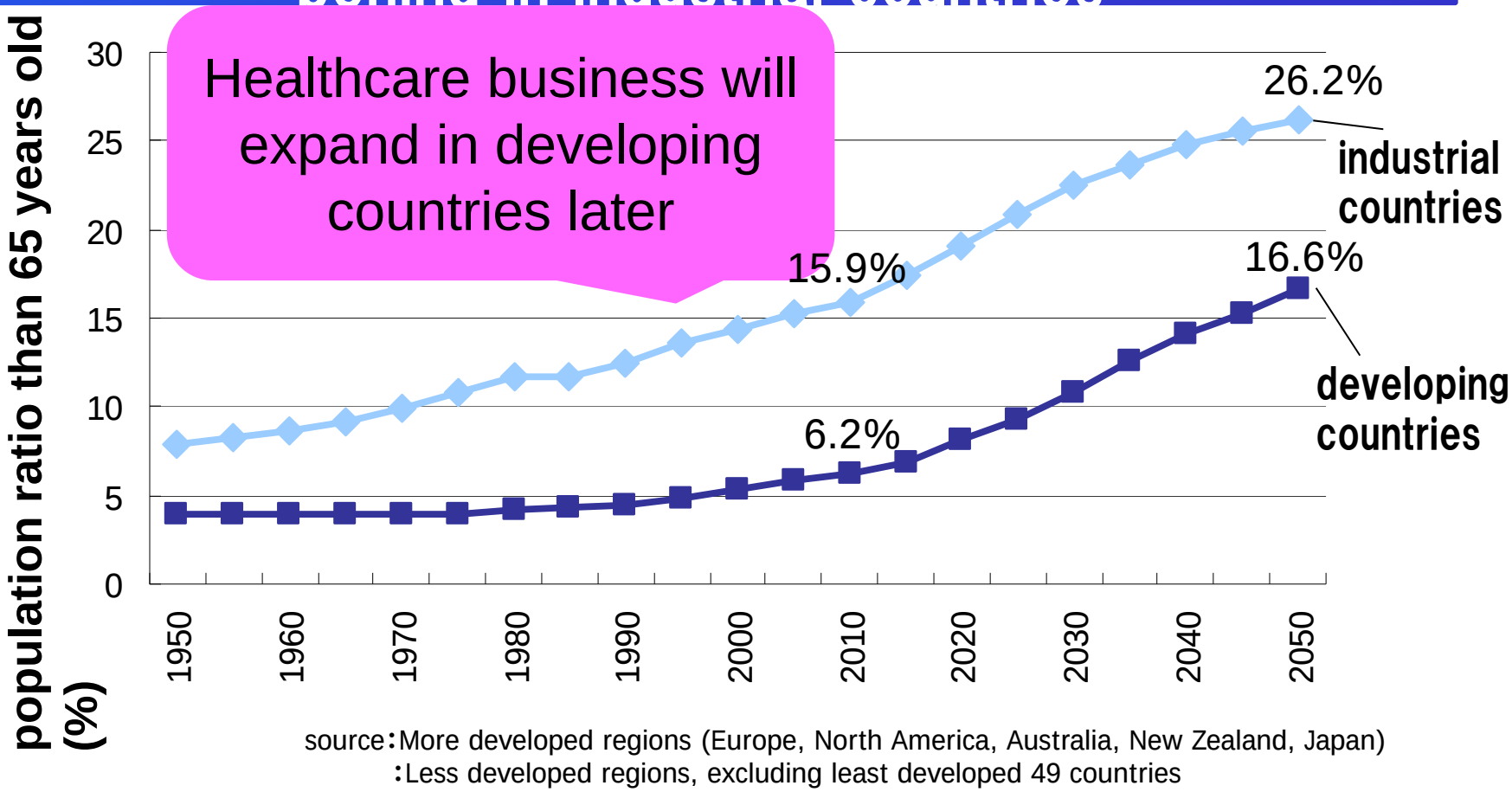
Dwindling birthrate and an aging population in industrial countries

Developing countries follow 30 or 40 years behind in industrial countries



source：More developed regions (Europe, North America, Australia, New Zealand, Japan)
：Less developed regions, excluding least developed 49 countries

（Source：United Nation World Population Prospect 2008）

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Cloud Networked Robotics

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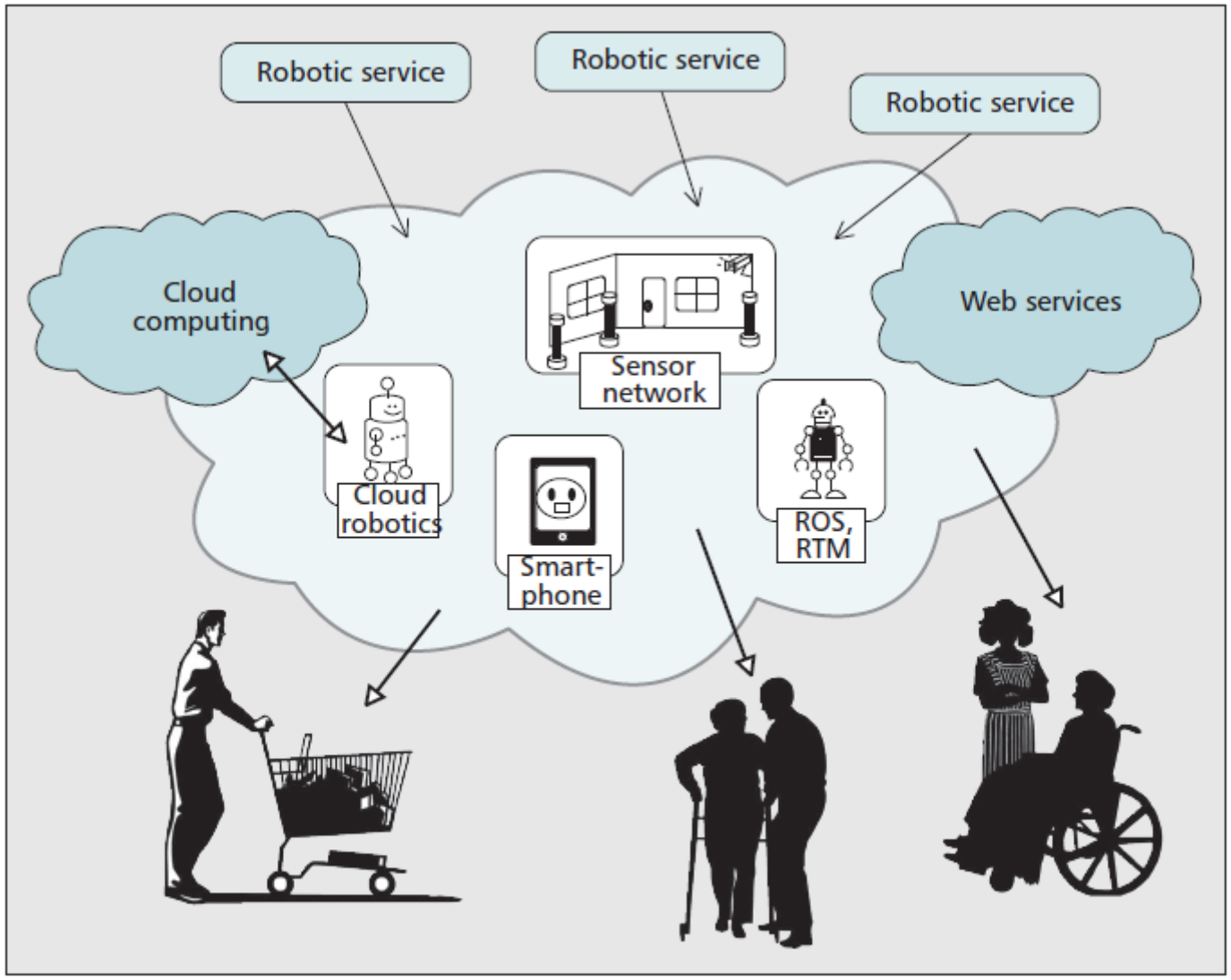

Figure 1. *In Cloud Networked Robotics, a platform layer located between service applications and robotic components isolates and coordinates them to realize multi-area, multi-robot networked robotic services.*

Courtesy of Dr. Kamei

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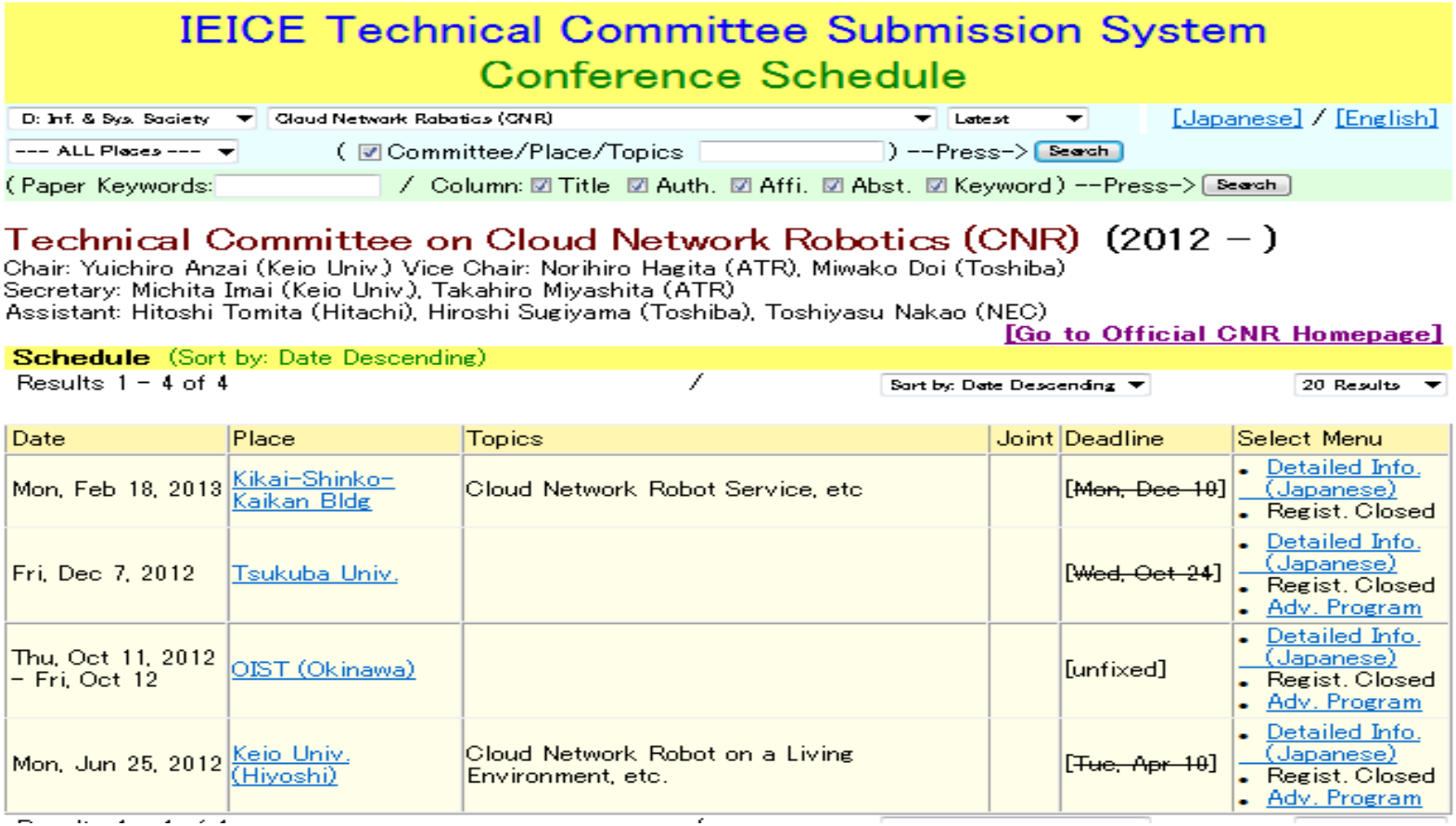
IEICE Technical Committee on Cloud Networked Robotics

- **Interaction between heterogeneous robots**
- **Interaction between human and robots**
- **Cloud data collaboration for networked robots**

http://www.ayu.ics.keio.ac.jp/cnr/



IEICE Technical Committee Submission System
Conference Schedule

D: Inf. & Sys. Society | Cloud Network Robotics (CNR) | Latest | [Japanese] / [English]

--- ALL Places --- | (Committee/Place/Topics) --Press-> Search

(Paper Keywords: / Column: Title Auth. Affi. Abst. Keyword) --Press-> Search

Technical Committee on Cloud Network Robotics (CNR) (2012 –)

Chair: Yuichiro Anzai (Keio Univ.) Vice Chair: Norihiro Hagita (ATR), Miwako Doi (Toshiba)
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[Go to Official CNR Homepage]

Schedule (Sort by: Date Descending)

Results 1 – 4 of 4 / Sort by: Date Descending | 20 Results

Date	Place	Topics	Joint	Deadline	Select Menu
Mon, Feb 18, 2013	Kikai-Shinko-Kaikan Bldg	Cloud Network Robot Service, etc		[~~Mon, Dec 10~~]	• Detailed Info. (Japanese) • Regist. Closed
Fri, Dec 7, 2012	Tsukuba Univ.			[~~Wed, Oct 24~~]	• Detailed Info. (Japanese) • Regist. Closed • Adv. Program
Thu, Oct 11, 2012 – Fri, Oct 12	OIST (Okinawa)			[unfixed]	• Detailed Info. (Japanese) • Regist. Closed • Adv. Program
Mon, Jun 25, 2012	Keio Univ. (Hiyoshi)	Cloud Network Robot on a Living Environment, etc.		[~~Tue, Apr 10~~]	• Detailed Info. (Japanese) • Regist. Closed • Adv. Program

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Brains on Clouds

- **Cleverbot http://www.cleverbot.com/**
- **Siri (Speech Interpretation and Recognition Interface)**
- **しゃべってコンシェルShabette_concier**

http://www.nttdocomo.co.jp/service/information/shabette_concier/

- **Animetrics**

http://animetrics.com/cloud-face-recognition-services/

:

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Elements of Cloud Networked Robotics

- **Data sensing**
- **Recognition**
- **Data mining**
- **Visualization and feedback**
- **Modeling**
- **Simulation**
- **Prediction**
- **Control**
- **Actuation**
- **Utilization**
- **Harmonization with human and robots**

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Acceleration Based Sensing

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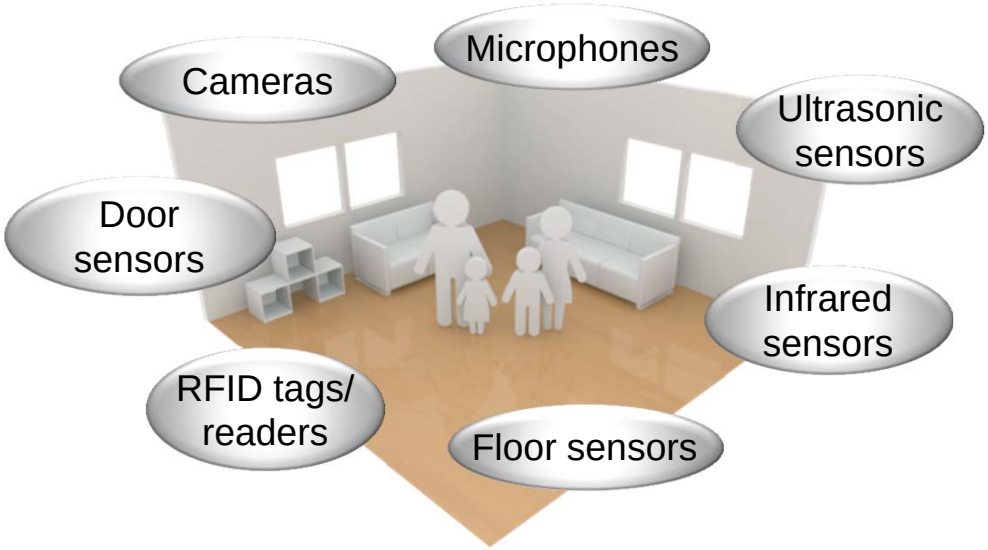
Related Works on Activity Recognition (1)



- Aware Home
  Georgia Tech. (1999)
- EasyLiving Project
  Microsoft Research (2000)
- YUKARI Project
  NiCT (2004)
- Sensing Room
  Univ. of Tokyo (2004)

Many sensors need to be installed in the environment.

➔ too costly to implement

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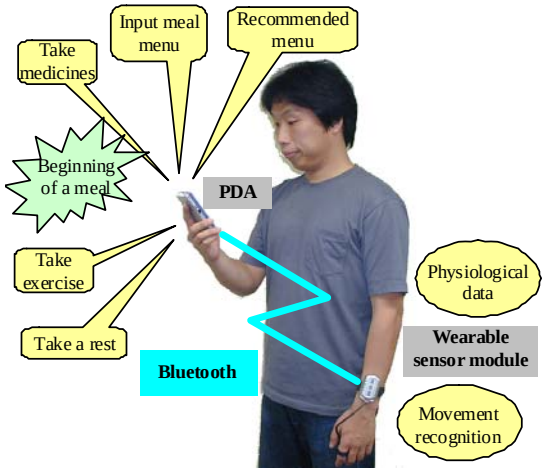
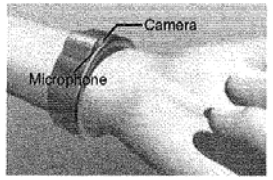
Related Works on Activity Recognition (2)

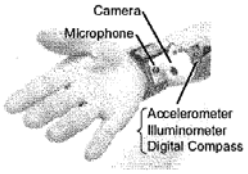


Toshiba (2002)

MIT (2004)



(a)



(b)

Fig. 1. (a) Conceptual image of wristband type sensor device and (b) prototype device

NTT (2010)

Various living activities have become recognizable by wearing sensors.

➔ Impracticable to continuously wear many accelerometers in daily life to use a special device from the viewpoint of the cost

Mobile phones / Smartphones

- are widely used.
- are always located close to users.
- are equipped with sensors such as an accelerometer and a GPS.

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Problems for Activity Recognition @ Smartphone

- **Problem 1: Focusing only outdoor migration activities**

(Related works)

(a) A three-axis accelerometer mounted on a cell phone

(b) Gait analysis browsing by Java applications

NTT DoCoMo (2006)

表 9：釈迦の推定性能[%]

	走	歩	転	電	バ	車	止
走	99.9	0.1	0.0	0.0	0.0	0.0	0.0
歩	0.0	96.3	0.3	0.2	2.6	0.0	0.4
転	0.0	0.0	88.9	0.0	0.0	11.1	0.0
電	0.0	0.0	0.0	84.6	6.0	0.0	9.4
バ	0.0	0.0	0.0	2.1	97.9	0.0	0.0
車	0.0	0.0	0.0	0.0	0.0	92.4	7.6
止	0.0	0.0	0.0	0.0	0.0	6.1	93.8

KDDI (2008)

  - It was difficult to recognize various indoor activities.

Objective 1:

Recognizing various indoor activities (ADL and IADL)

- **Problem 2: Power consumption**

Objective 2:

Developing a low power consumption algorithm

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Indoor Activity Recognition @ Smartphone

Recognizing various indoor activities (ADL and IADL)

- **Using not only an accelerometer but also a microphone**
  - Hybrid activity recognition focused on the sound

Developing a low power consumption algorithm

- **Rough classification of movement by acceleration**
  - "Walking," "Quiet," and "Performing a living activity"
- **Classification of the nature of the task by sound**

Data	Resolution, Sampling Frequency	Data size per 1 sec. (Bytes)
3-axis acceleration	10bit, 20Hz	75
Sound	16bit, 16kHz	32,000

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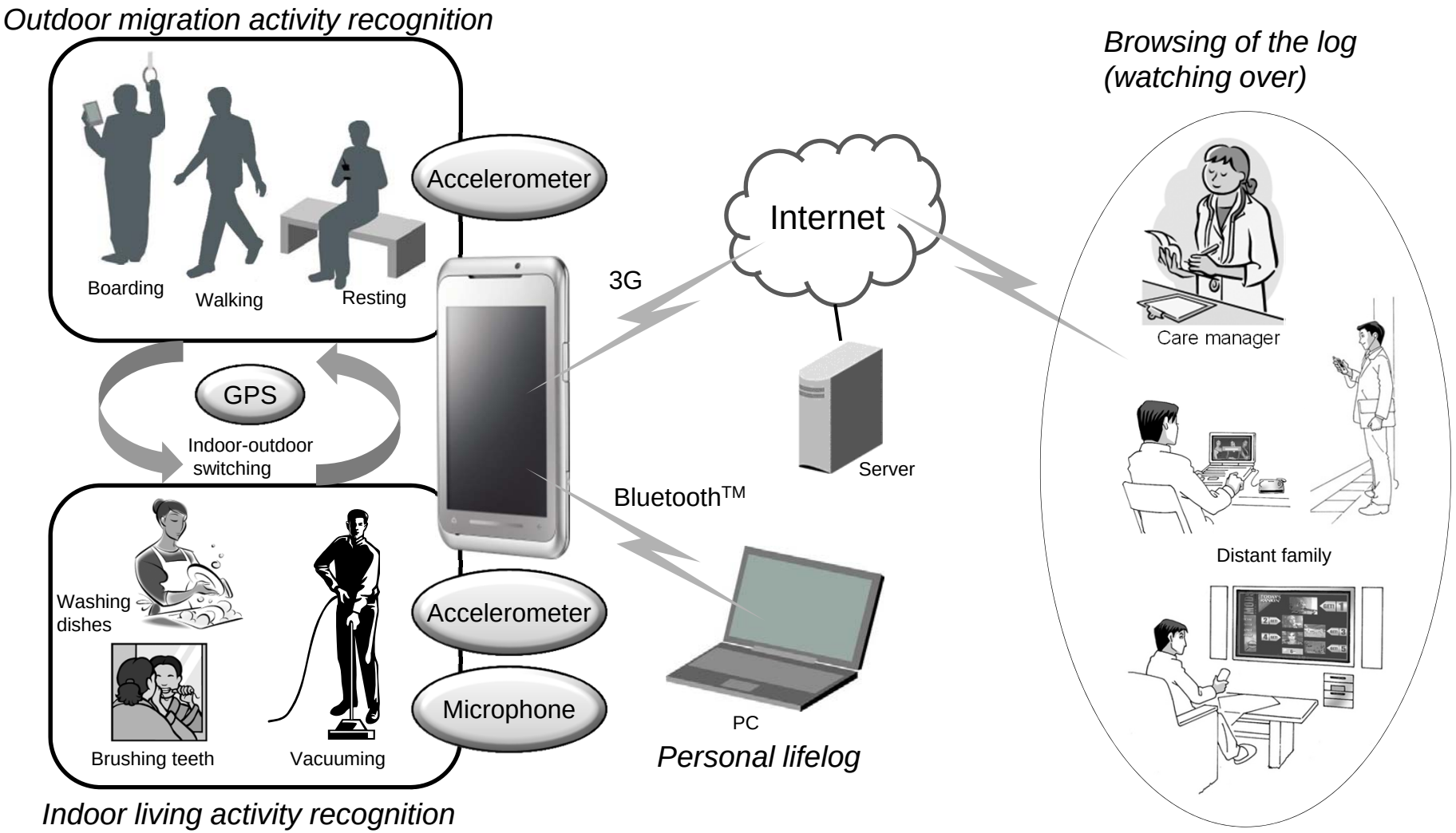
Indoor-Outdoor Activity Recognition @ Smartphone



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Indoor-Outdoor Activity Recognition by a Smartphone

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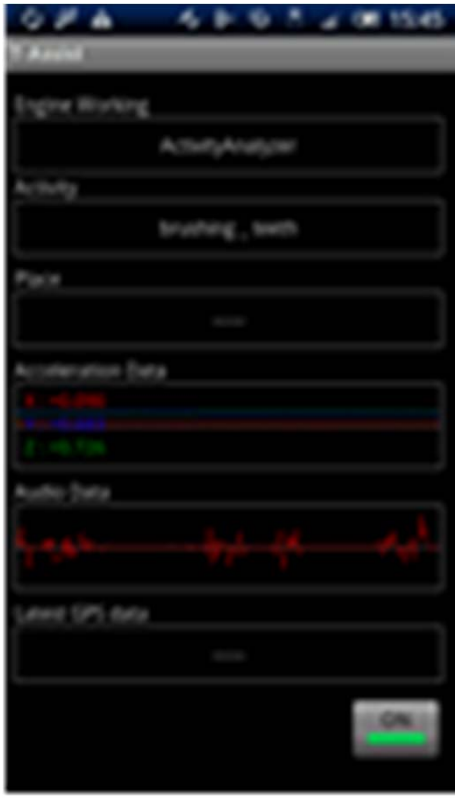

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Features

- **Recognizing various indoor-outdoor activities in real time by using a commonly-used smartphone**
  - Sensors
    - 3-axis accelerometer, microphone, GPS
  - Combined an indoor living activity recognition engine and an outdoor migration activity recognition engine

- **By switching between the 2 engines depending on an acquisition condition of GPS satellites**
  - Enables users to continuously recognize indoor-outdoor activities

- **A transmitting function to a cloud server or an external terminal via 3G networks or Bluetooth™**
  - In anticipation of various practical services

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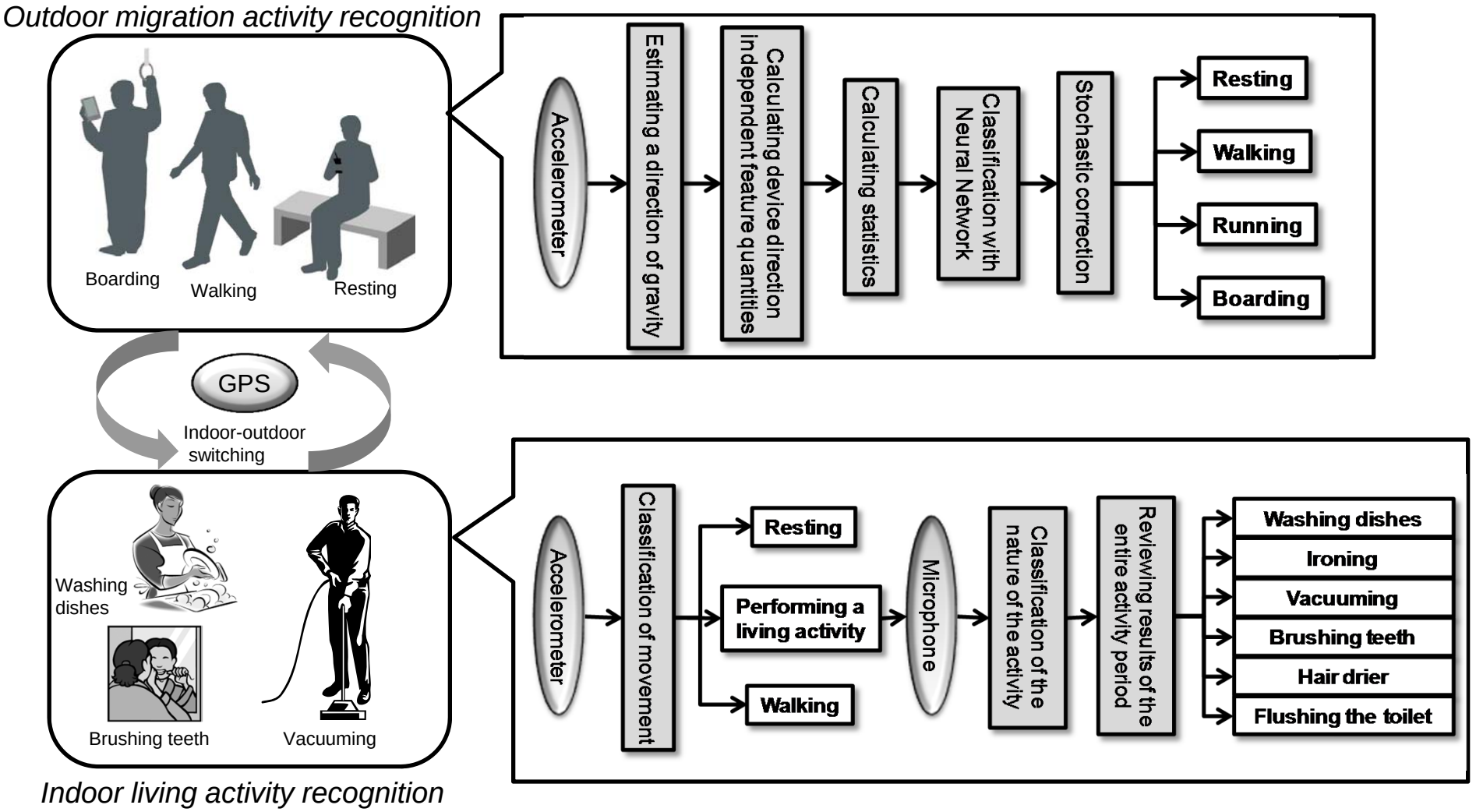
Processing Flow



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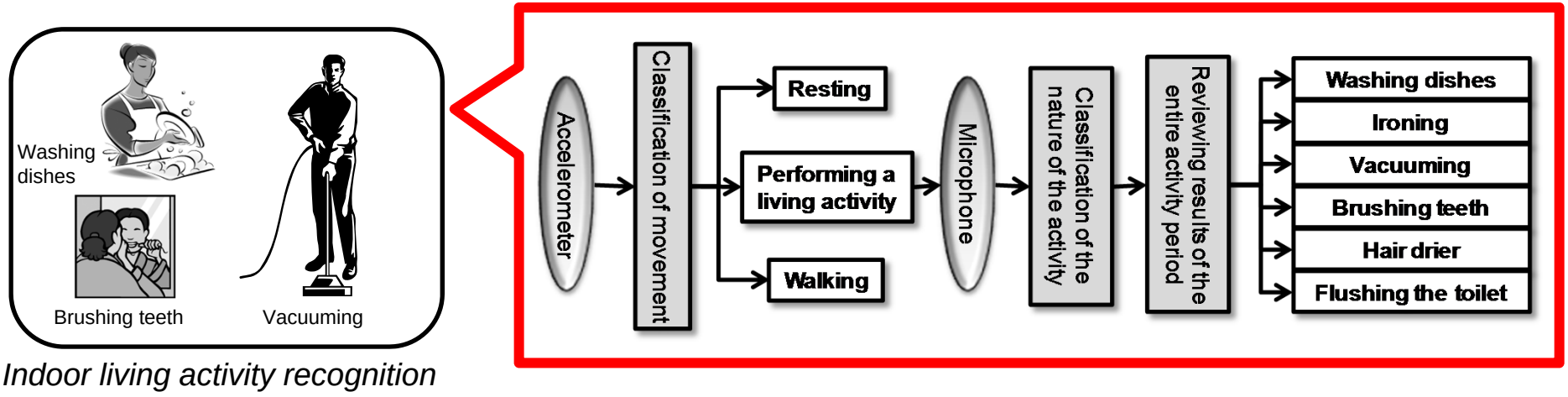
Indoor Living Activity Recognition Engine



Indoor living activity recognition

1. **Roughly classifies the user's movement into "Resting," "Walking," and "Performing a living activity"**

2. **When it classifies "Performing a living activity," it activates the microphone to recognize various living activities.**

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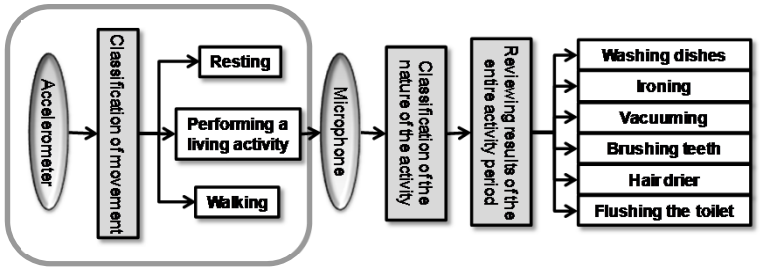
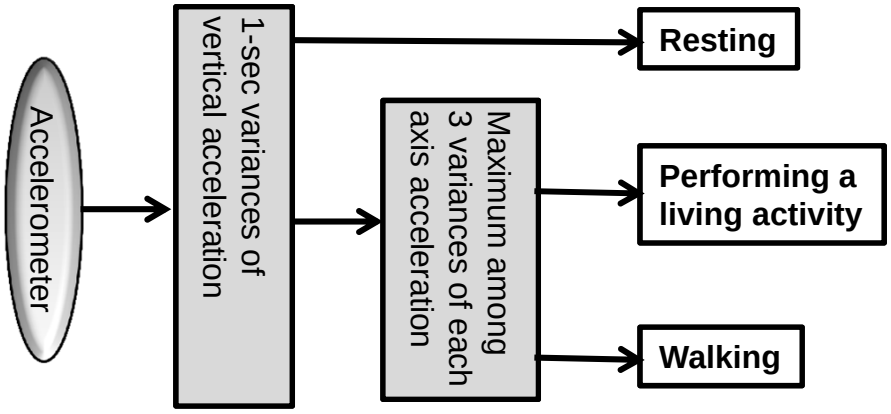
Movement Classification by Acceleration

- **Low throughput algorithm**
  - 10bit, 20Hz sampling
  - Using variances of 1-sec data series





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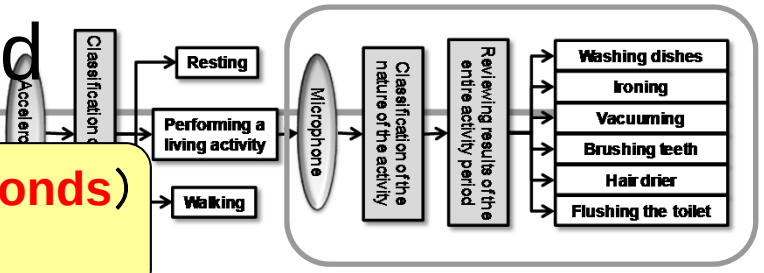
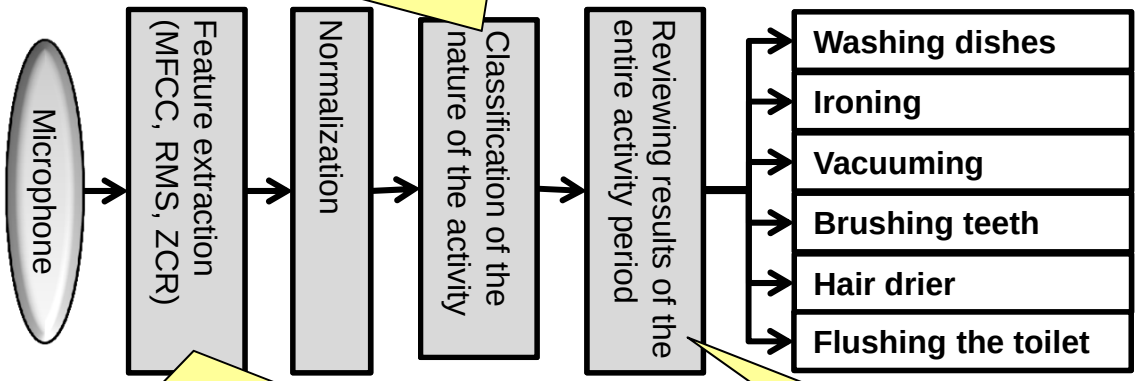
Activity Classification by Sound



- **Train each target activity beforehand（10 seconds）**
- **Classifier: SVM（Support Vector Machine）**

•Classifying every 1 second



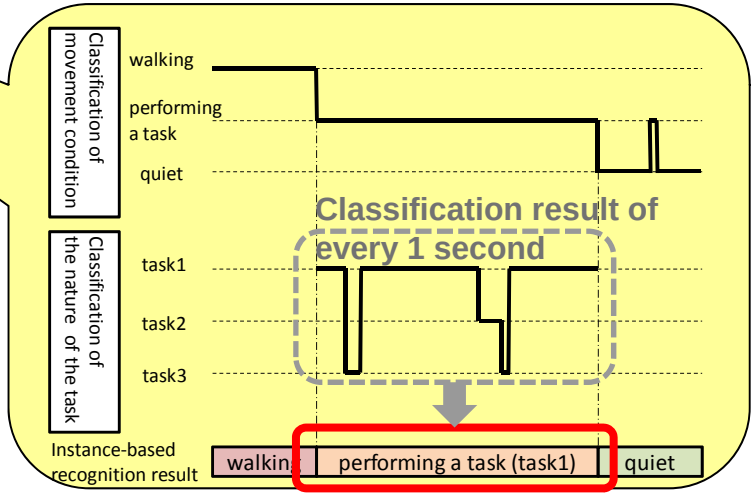
- MFCC (Mel Frequency Cepstral Coefficients)
- RMS (Root Mean Square)

$$a_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} a_i^2}$$

- ZCR (Zero-Crossing Rate)

$$a_{zcr} = \frac{1}{N-1}\sum_{i=2}^{N} F\{a_i a_{i-1} < 0\}$$

•16bit, 16kHz sampling
•Calculating averages of each feature every 1 second



Additional recognition result by majority voting

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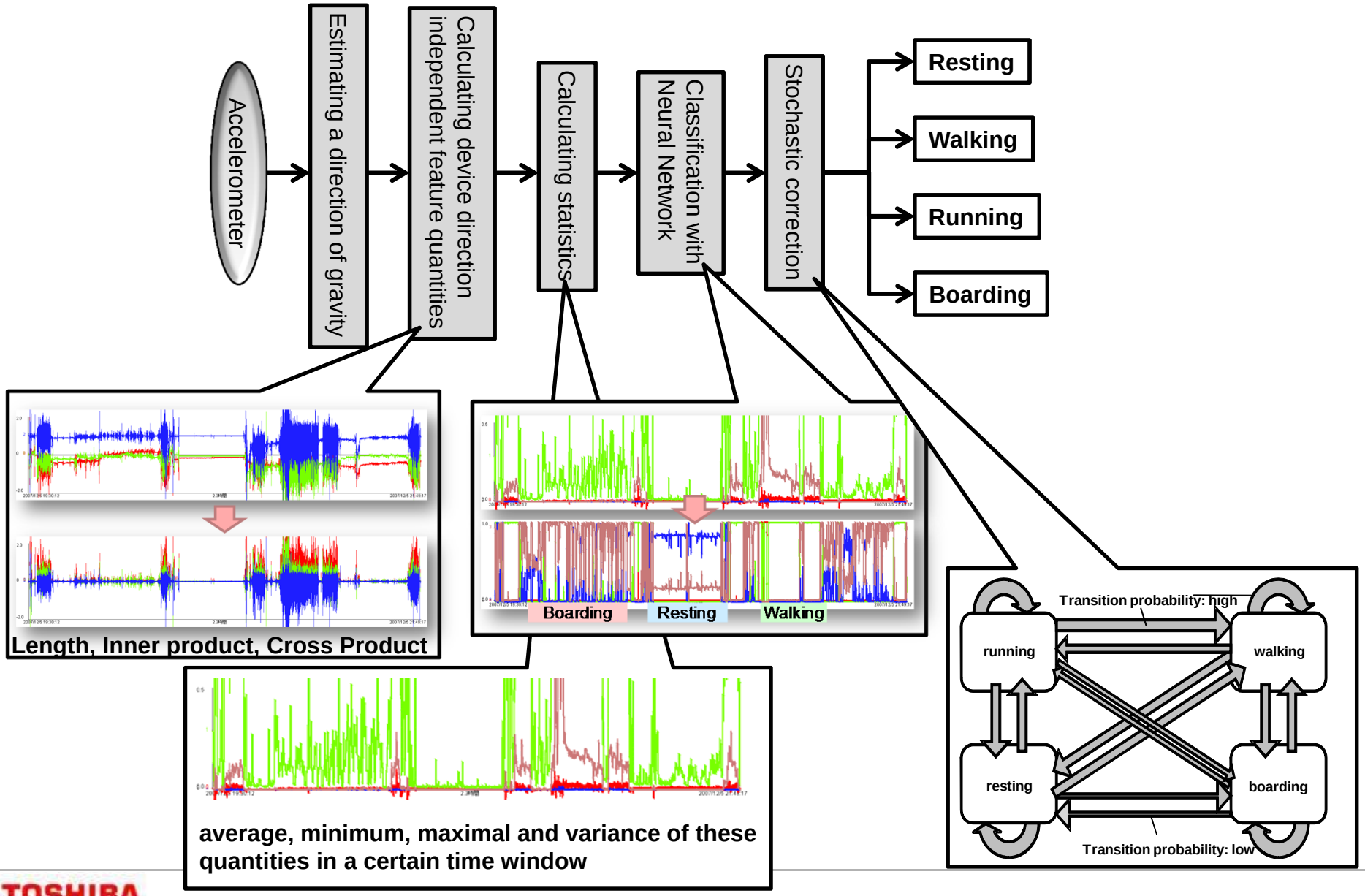
Outdoor Migration Activity Recognition Engine



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Evaluation Experiment

- **Indoor Living Activity Recognition**
  - **21 subjects**
    - 6 men and 6 women in their 60s
    - 5 men and 4 women in their 20s to 40s

    @ a mock living room

  - **Target living activities**
    - “Washing dishes,” “Ironing,” “Vacuuming,” “Brushing teeth,” “Hair drier,” and “Flushing the toilet.”
      - First, they performed each activity for 10 seconds.
      - Then, we directed them to perform all the target activities.
      - We did not direct them how to spend the intervals between the target activities.
      - An untrained task might occur during the intervals.
      - It should be considered to be an untrained task.

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Indoor Living Activity Recognition Accuracy

Movement classification accuracy by acceleration

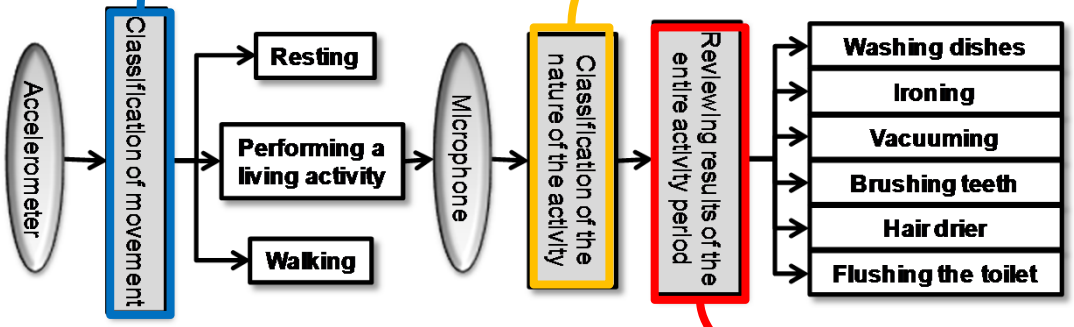
Rough movement	Accuracy(%)
Walking	95.2
Performing a living activity	96.8
Resting	96.5

Raw activity classification accuracy every 1 second 84.5%

Living activity	Accuracy(%)
Washing dishes	80.2
Ironing	76.7
Vacuuming	86.3
Brushing teeth	74.1
Hair drier	96.4
Flushing the toilet	93.2

91.4%

Accuracy(%)
88.1
85.7
100
85.7
100
97.6



Final classification accuracy by majority voting

	Trained tasks						Untrained task	Accuracy (%)
	Washing dishes	Ironing	Vacuuming	Brushing teeth	Hair drier	Flushing the toilet		
Washing dishes	37			3		1	1	88.1
Ironing		36		4			2	85.7
Vacuuming			42					100
Brushing teeth		3		36			3	85.7
Hair drier					42			100
Flushing the toilet						41	1	97.6
Untrained task	3	7		4		4	87	82.9

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Outdoor Migration Activity Recognition Accuracy

- **Trial subjects carry the cellular phone in daily life**
  - Number of subjects: 4 (our project members)
  - Total number of hours: 56 hours 31 minutes

Correct answer

Estimated result	Running	Walking	Resting	Boarding
Running	92.5	0.0	0.0	0.0
Walking	7.4	99.4	1.1	1.4
Resting	0.0	0.1	97.5	2.6
Boarding	0.0	0.4	1.3	95.6
Unknown	0.1	0.1	0.1	0.3

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Future Work

- **Performance evaluation in an actual usage environment**
  - Recognition accuracy
  - Power consumption
- **Considering the measures in case that users doesn't carry their smartphone on them inside the house**
  - Use of sensors equipped with commonly-used digital products and home appliances
- **A number of business under consideration**
  - Tele-monitoring service
  - Healthcare service
  - Energy saving in cooperation with HEMS
  - Routine inspection task support system
  - BEMS, Smart office, etc.

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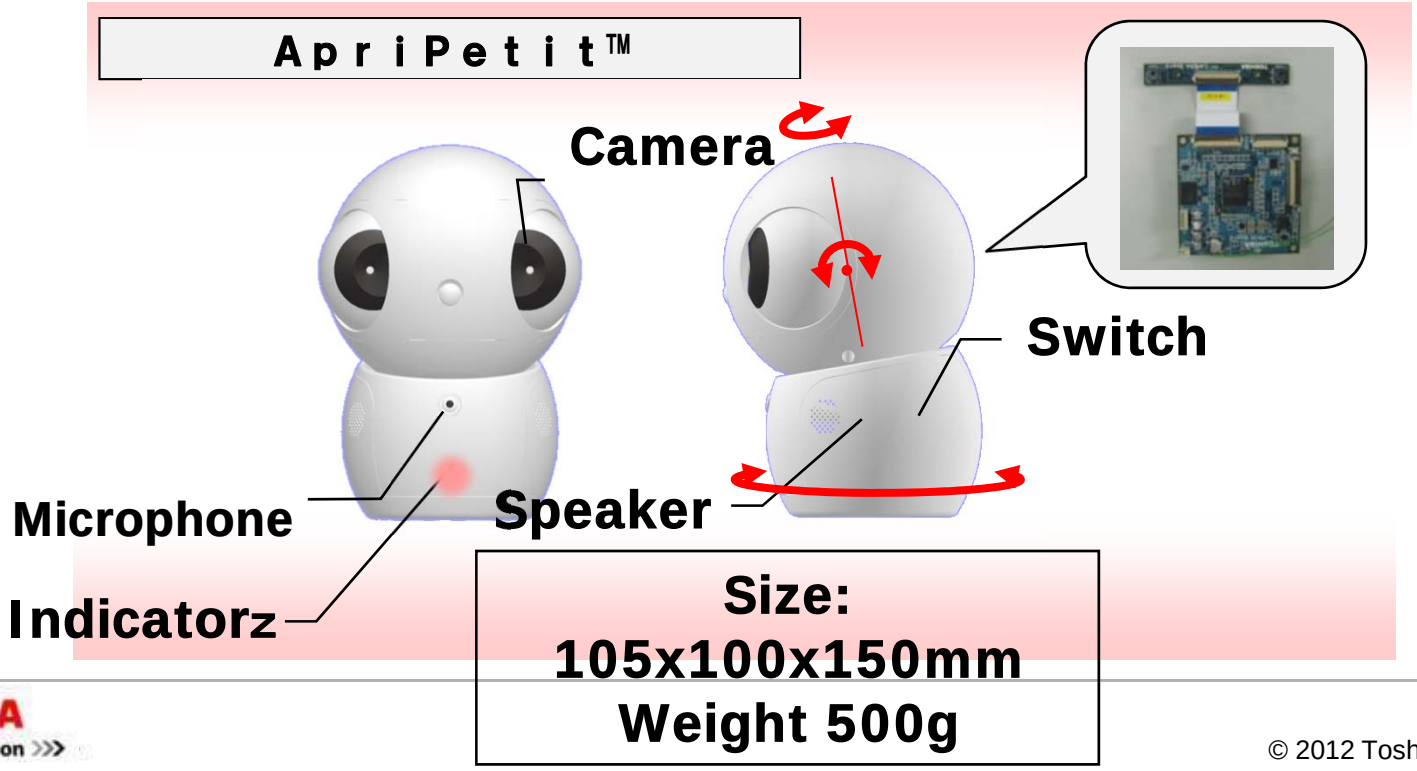
Hand held IF Robot : ApriPetit™

Hand held size

- Image processing inside and speech processing cloud



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Thank you.

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