Next-Generation Multi-Function Intelligent Nursing Care System

CASE 2014 Workshop on Advanced Intelligent Automation Technology

PI : *Li-Chen Fu*

Co-PI : Yo-Ping Huang, Kuang-Yow Lian, Zai-Ting Yeh, Yen-Lin Chen, Hsin-Han Chiang, and Cheng-Ming Huang

National Taiwan University, National Taipei University of Science & Technology, Fu Jen Catholic University

Outline

- Introduction
- System Overview
- Robotic Assistance
- Environmental Monitoring and HCI
- Physiological Monitoring and Cognitive Support
- Conclusion

Introduction

- Traditional Nursing Home
  - Lack of enough professional care
  - Crowded and unfriendly environment
  - Insufficient cognitive monitoring and stimulation

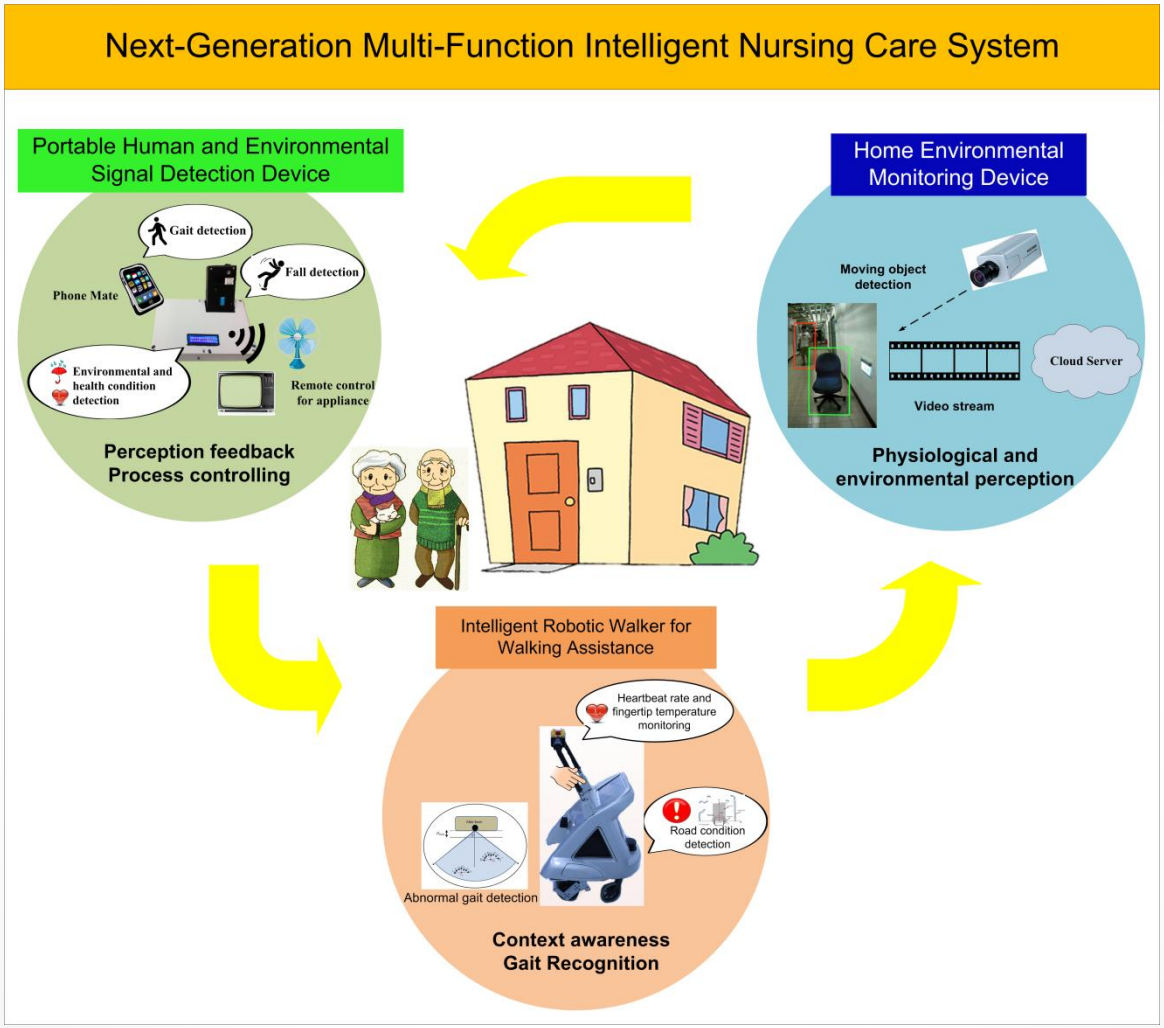
Introduction

- Next Generation Nursing Care Unit
  - Providing convenient and comfortable service
  - Assisting the elders in daily life
  - Reducing the burden from caregiver and their family

Introduction

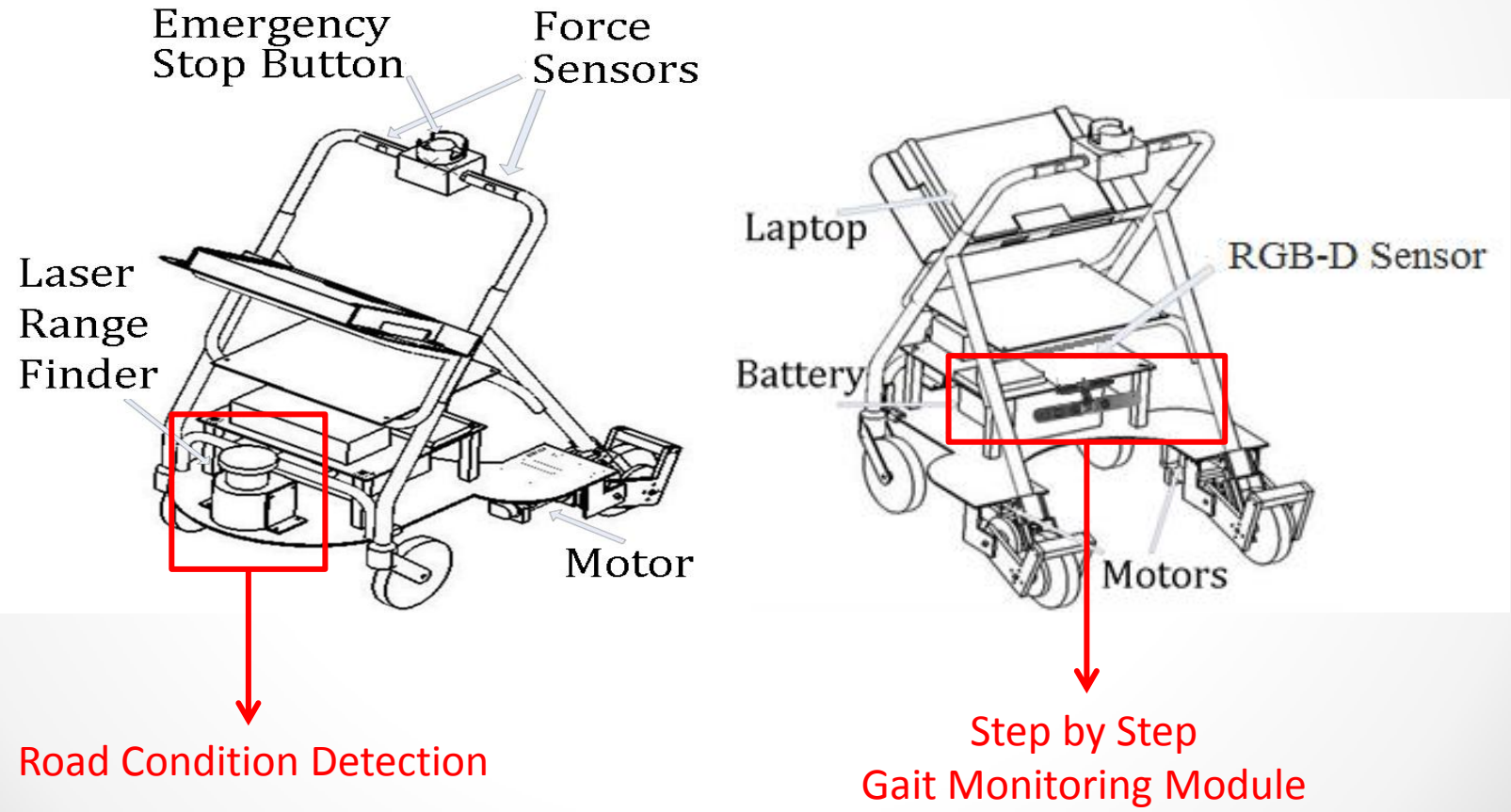
- Research Goal
  - Intelligent hand-held device sensing service
  - Intelligent assistive robotic walker and living-aid robot
  - Instant home video surveillance system

System Overview



Robotic Assisted Nursing Home

- Intelligent Assistive Robotic Walker

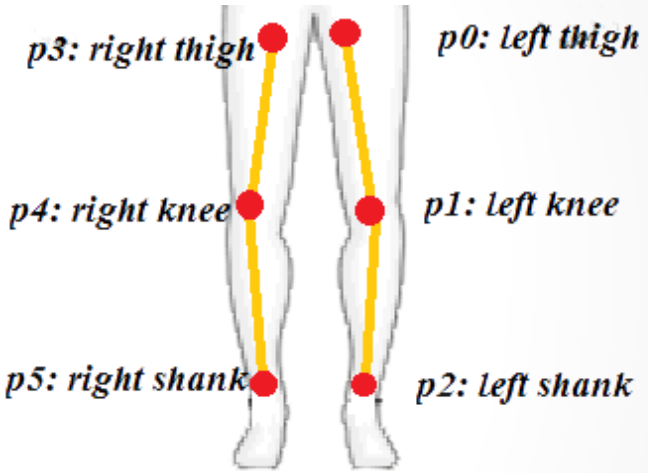


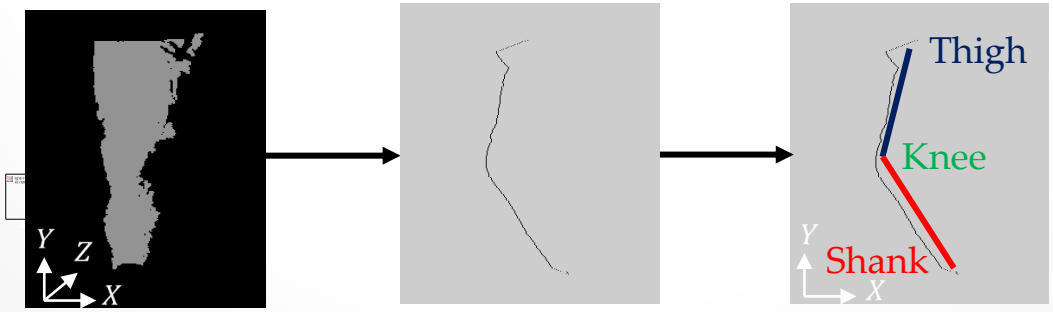
Intelligent Assistive Robotic Walker

- Gait Monitoring Module - Gait Analyzer
  - Joint Position Tracking
    - Apply particle filter for human gait tracking
  - Gait Feature Extraction
    - Step length, step velocity, and joint angle
  - Gait Identification by Hidden Markov Model
    - Abnormal gait : Festinating of gait, Freezing of gait
    - Normal gait

Intelligent Assistive Robotic Walker

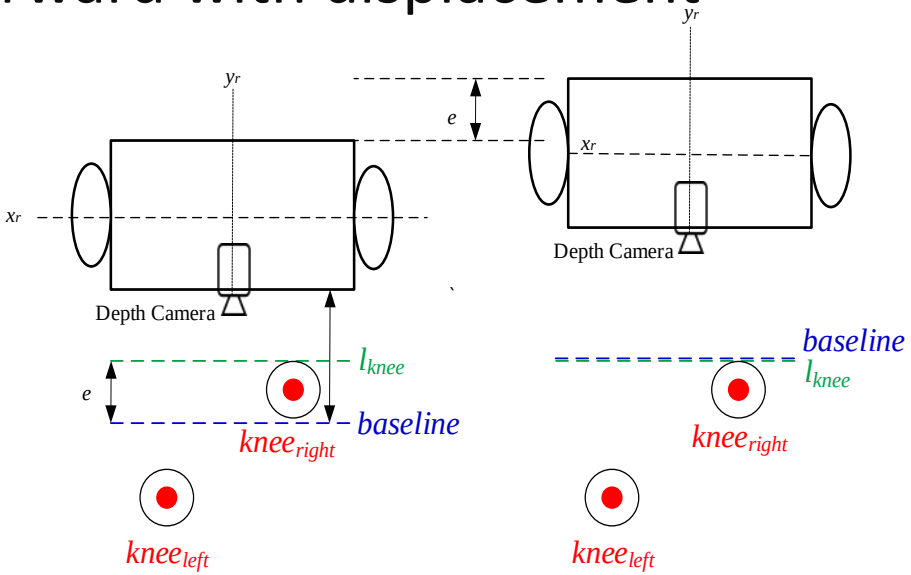
- Gait Monitoring Module – Gait Analyzer
  - Human Gait Model
    - Knee Joint
    - Thigh point
    - Shank point
  - Joint Detection





Intelligent Assistive Robotic Walker

- Step-by-Step Function
  - Baseline : distance between walker and user
  - Move forward until the baseline reached the front leg l_{knee}
  - Move forward with displacement ε

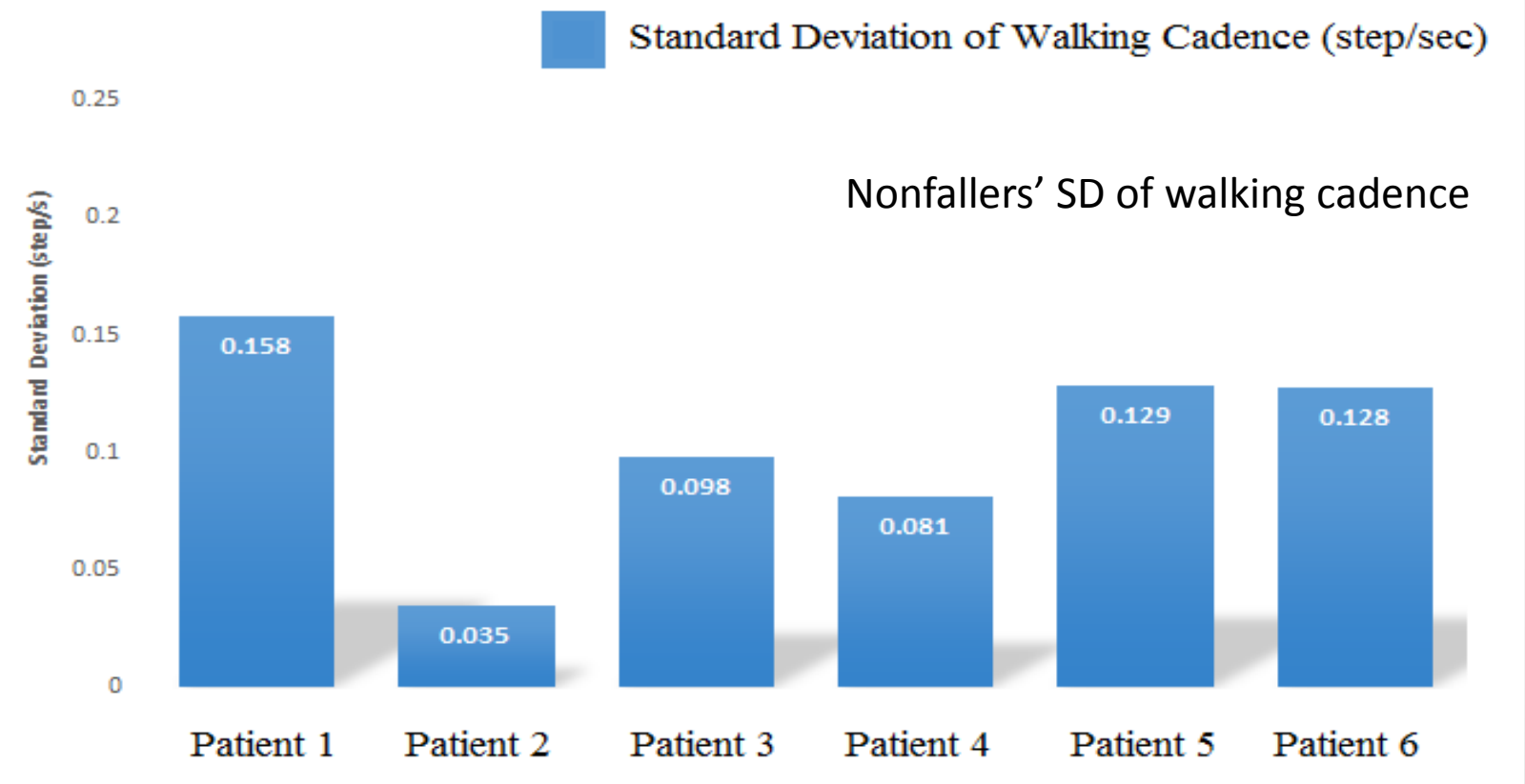


Intelligent Assistive Robotic Walker

- Gait Monitoring Module - Stabilizing System
  - Target
    - Recover user's regular walking situation after abnormal gait occurs
  - Guidance for Parkinson Disease patients
    - Auditory cue : Broadcast frequency
    - Walker movement cue : Velocity of walker
  - Adjusting Result
    - User's walking situation after guiding

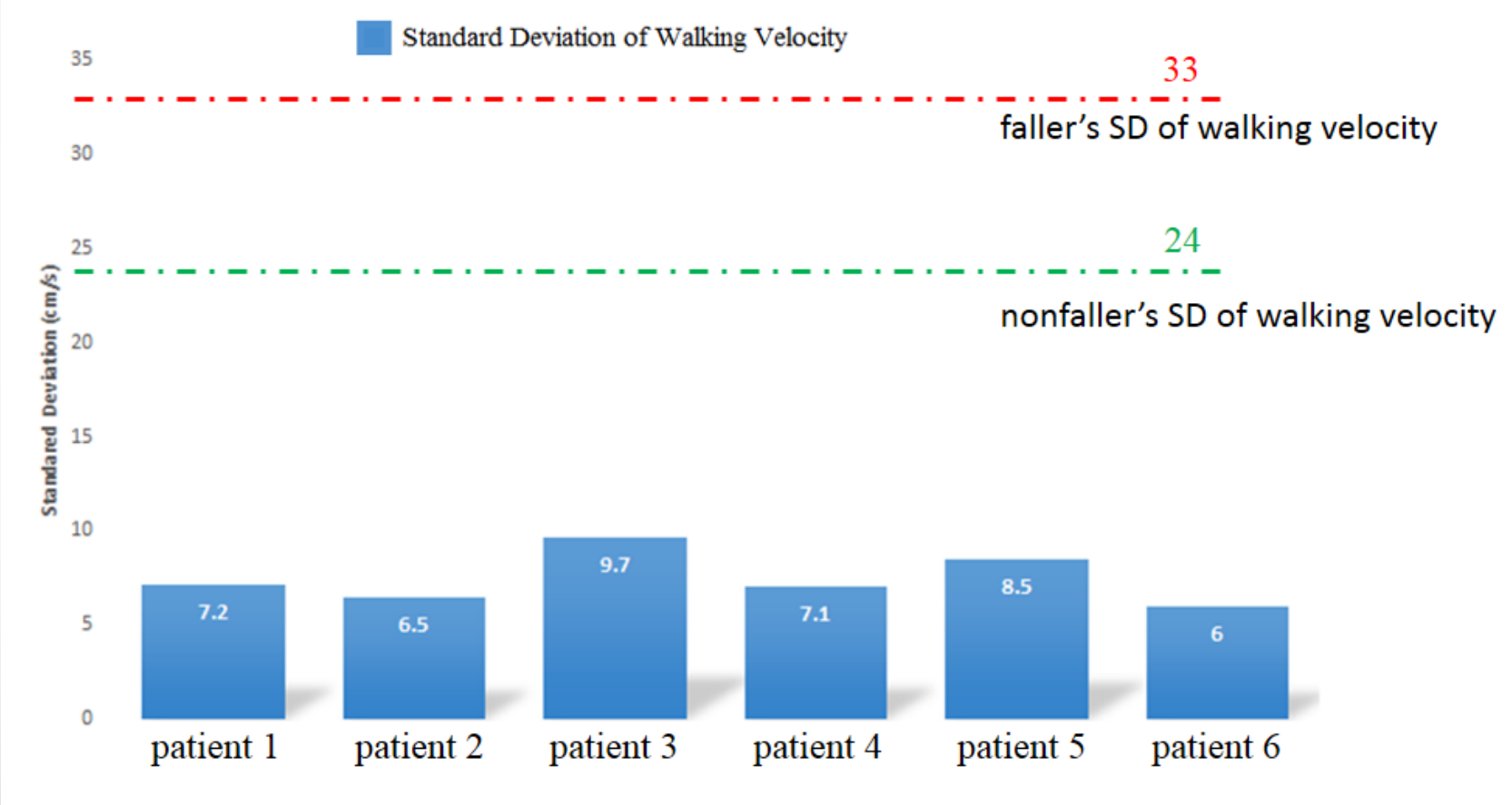
Experiment Result

- Evaluate Walking Cadence (step/sec)



Experiment Result

- Standard Deviation of each Patient



Demonstration

Robotic Living Aid

- Fetching objects by grasp planning
  - To solve the problem due to the inconvenience of the elders
  - To remove the obstacles in order to grasp the target

Image Process and Segmentation

- 3D Image Capture by RGB-D Camera
- Objects Segmentation with Point Cloud Library

Sequence Planning

- Using A* planning algorithm to find the best grasping sequence.
- State:
  - $S = \{RemainObject,\ RobotPosition\}$
- Cost:
  - $C_{S_i S_j} = T_m\left(P_{S_i}, P_{S_j}\right) + T_{Grasp} + T_{Put}$

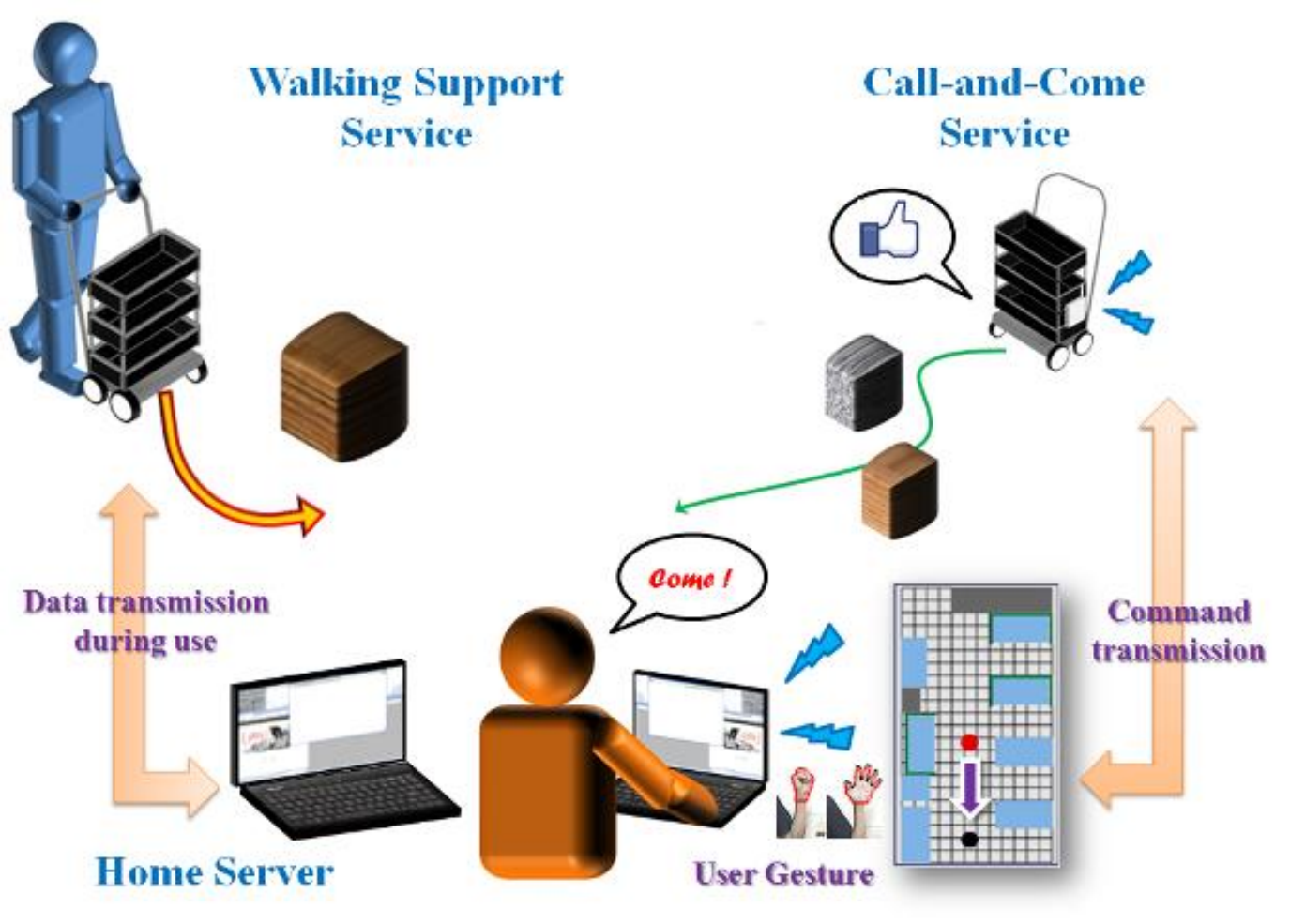
$C_{S_i S_j}$: cost from state i to state j

$T_m\left(P_{S_i}, P_{S_j}\right)$: moving time for robot from position i to position j

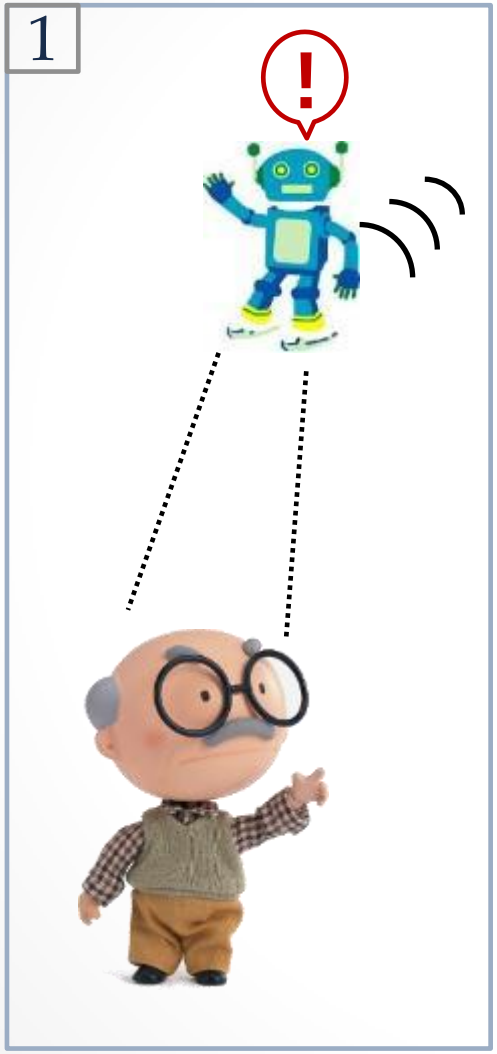
T_{Grasp} : grasping time for robot

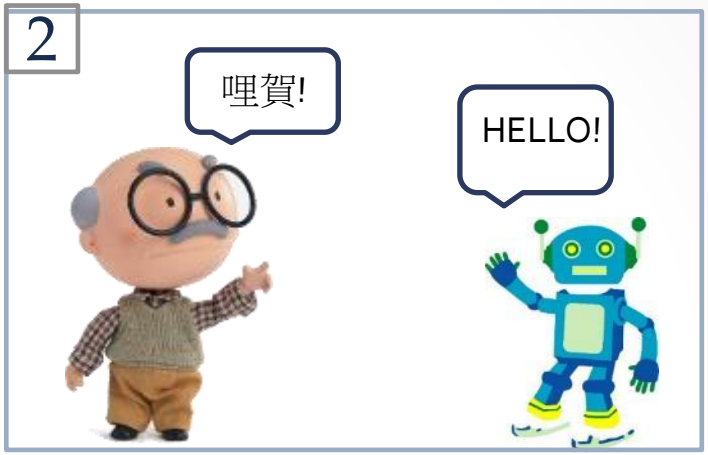
T_{Put} : putting time for robot

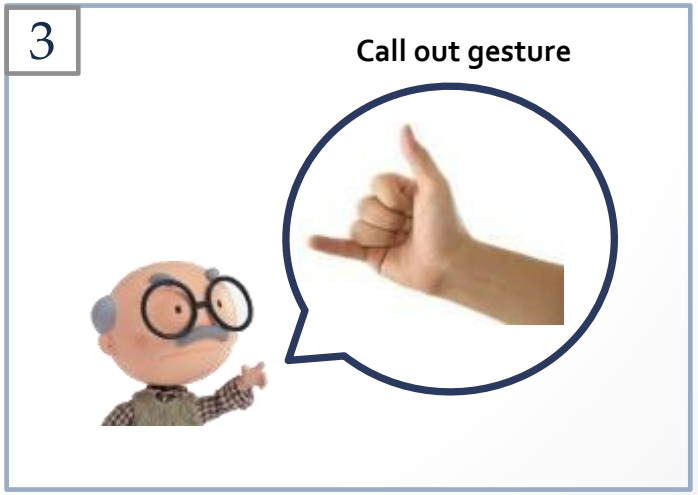
Environmental Monitoring and HCI



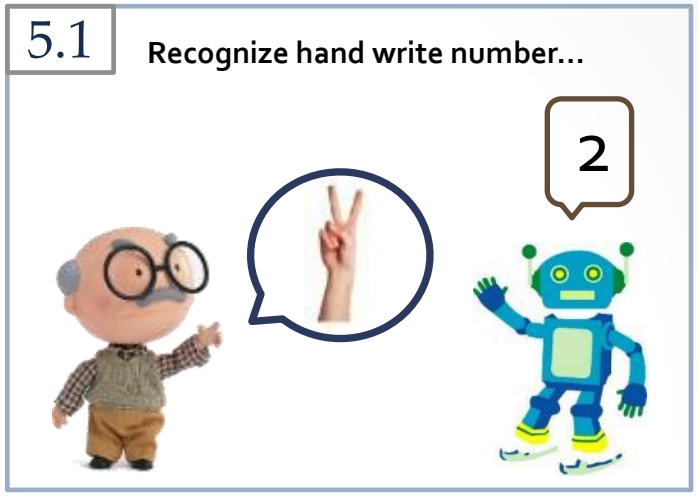
Natural Human Robot Interaction

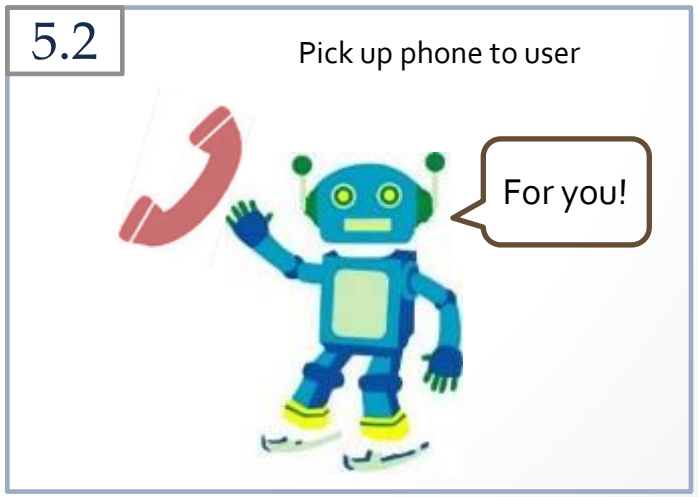






Natural Human Robot Interaction

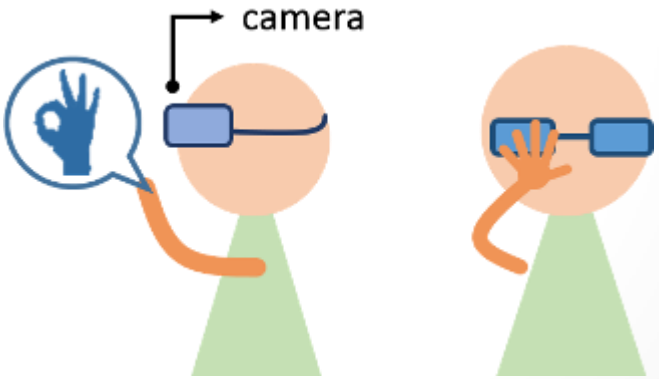




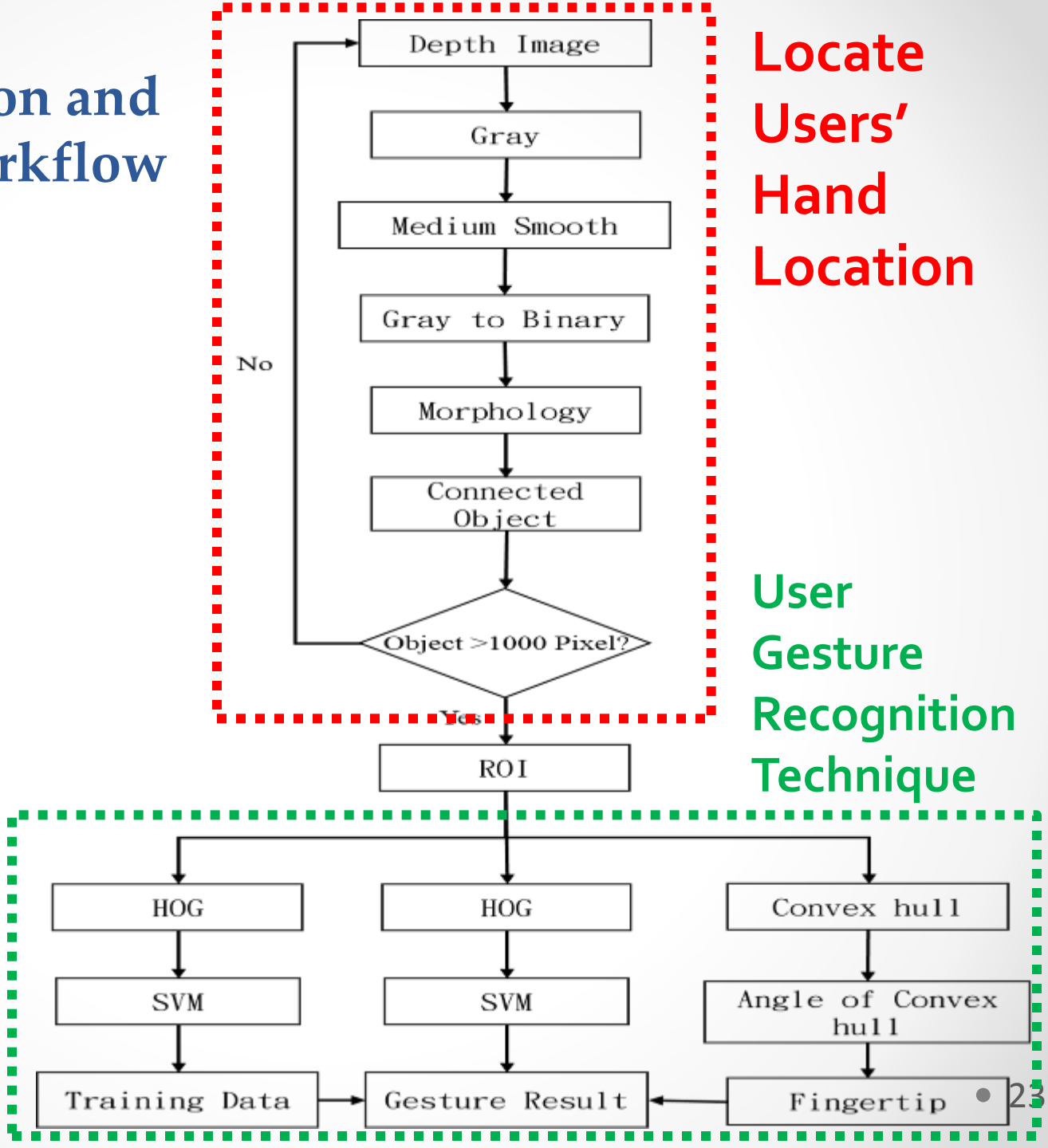
Visual Surveillance

Hardware Device and Scenario

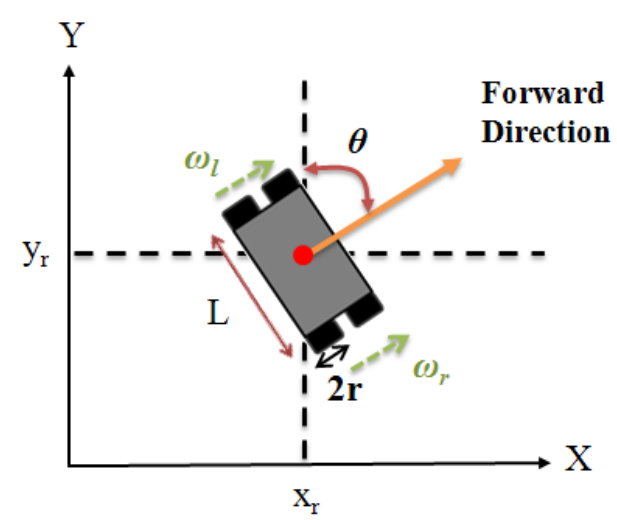
- Camera：Etron 3D Depth-map Camera - eSP870



Gesture Detection and Recognition Workflow



Intelligent Navigation – Robot Dynamics



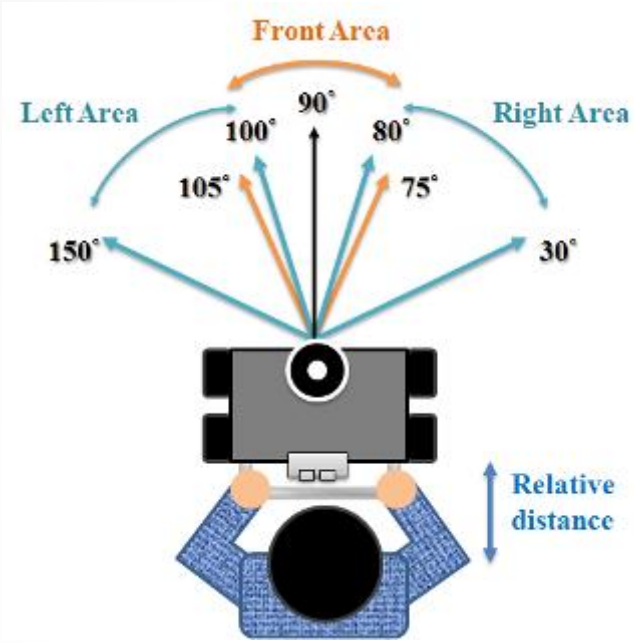
$$\begin{cases} \dot{x} = \frac{1}{2} r(\omega_r + \omega_l)\sin\theta \\ \dot{y} = \frac{1}{2} r(\omega_r + \omega_l)\cos\theta \\ \dot{\theta} = \frac{r}{L}(\omega_r - \omega_l) \end{cases} \quad (3)$$

$$\begin{bmatrix} \dot{x}_r \\ \dot{y}_r \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \sin\theta & 0 \\ \cos\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \quad (1)$$

$$\begin{aligned} v &= \frac{r}{2}(\omega_r + \omega_l) \\ \omega &= \frac{r}{L}(\omega_r - \omega_l) \end{aligned} \quad (2)$$

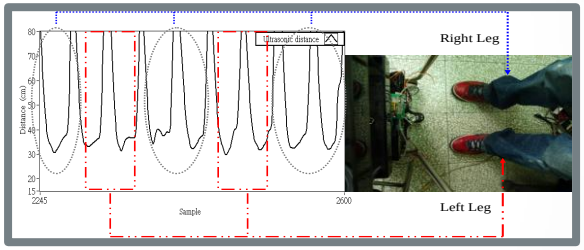
$$\begin{cases} x_{t+1} = x_t + \frac{1}{2} r \sin\theta_t(\omega_r + \omega_l)\Delta t \\ y_{t+1} = y_t + \frac{1}{2} r \cos\theta_t(\omega_r + \omega_l)\Delta t \\ \theta_{t+1} = \theta_t + \frac{r}{L}(\omega_r - \omega_l)\Delta t \end{cases} \quad (4)$$

Intelligent Navigation – Obstacle Avoidance

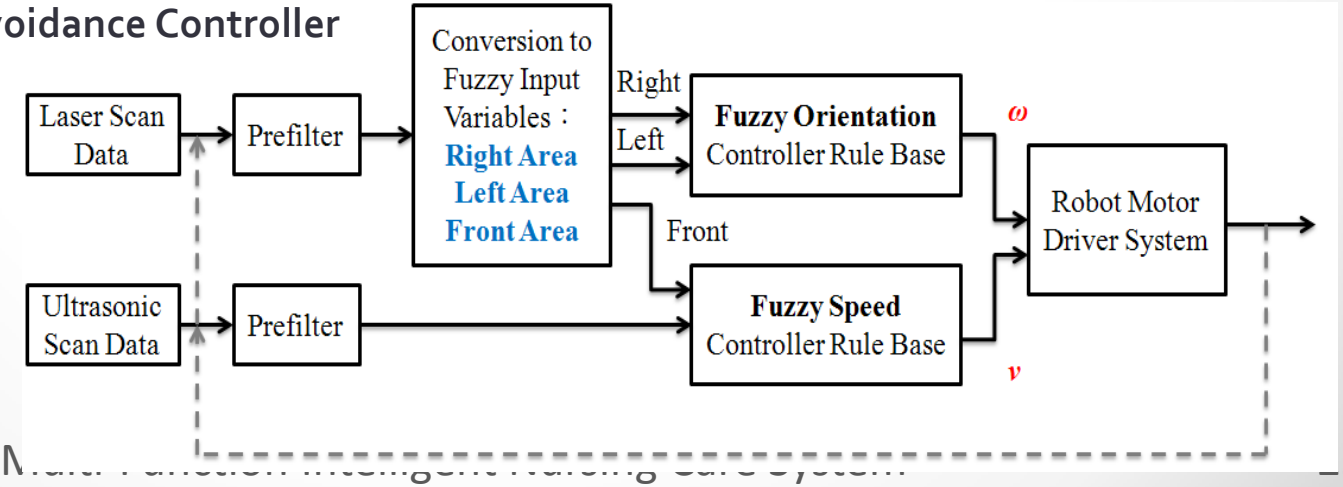


Laser Scanner

Ultrasonic Sensor

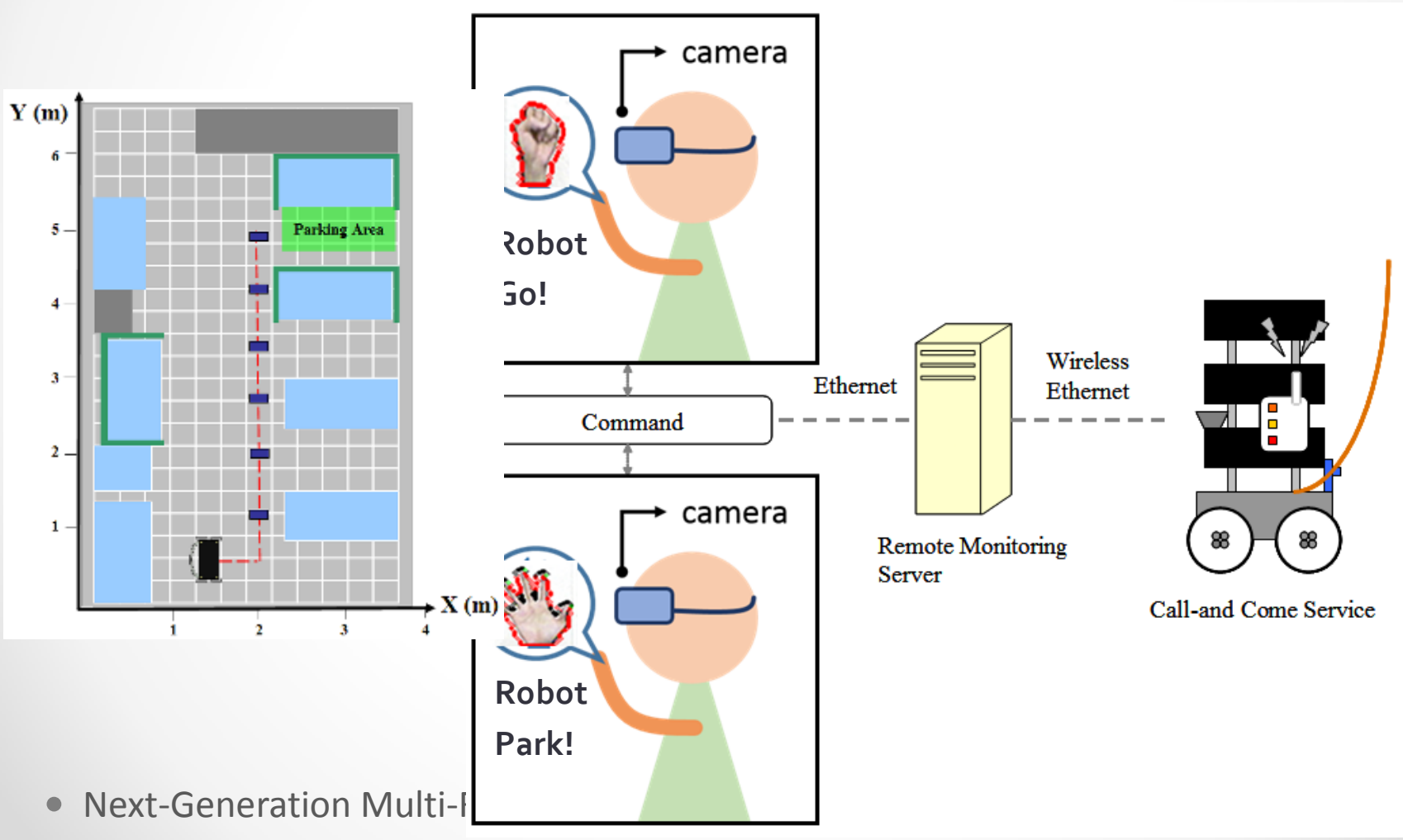


- **Fuzzy Obstacle Avoidance Controller**

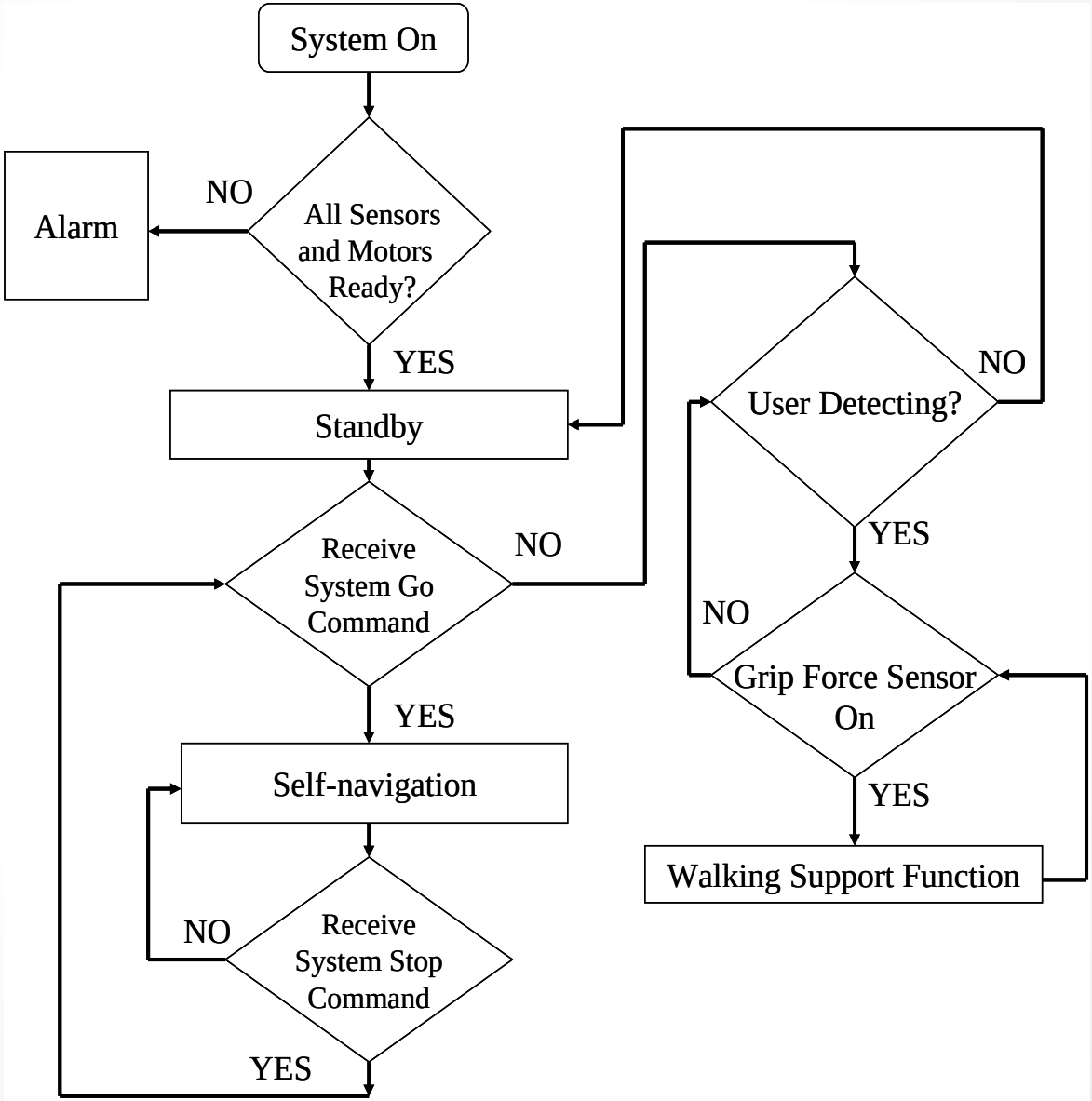


- Next-Generation M[illegible] Intelligent Nursing Care System

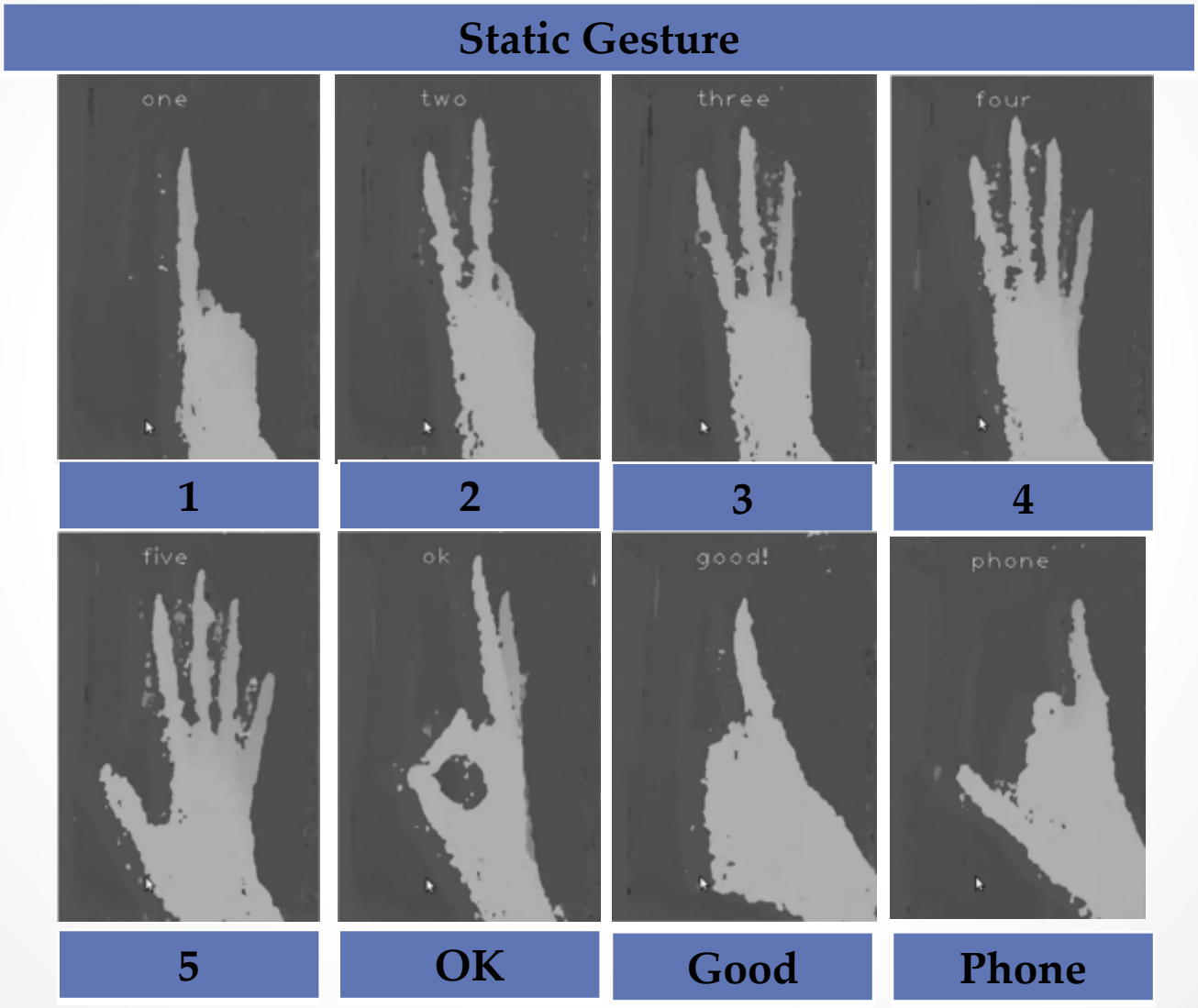
Intelligent Navigation – Call-and-come Service



Intelligent Navigation–Call-and-come Service Flowchart

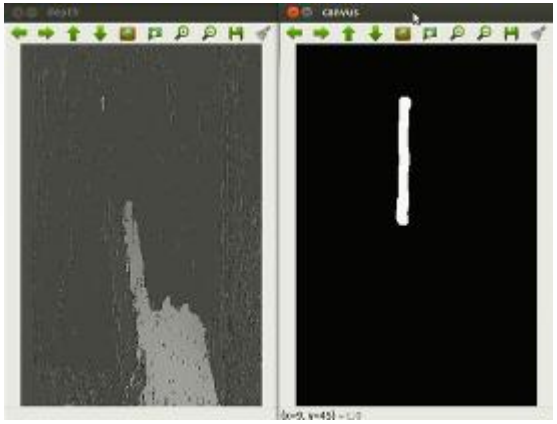


Experimental Results

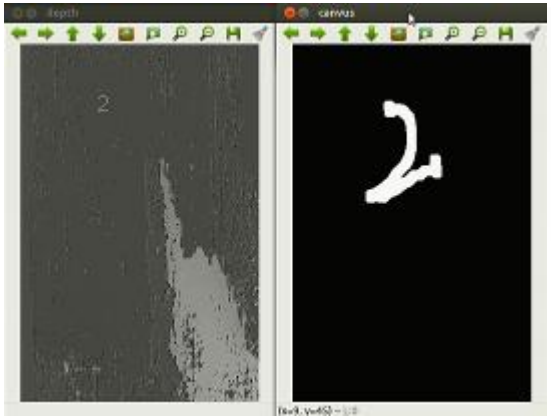


Experimental Results

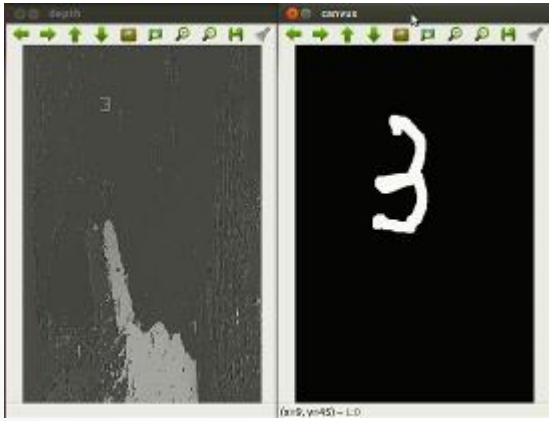
Dynamic Gesture



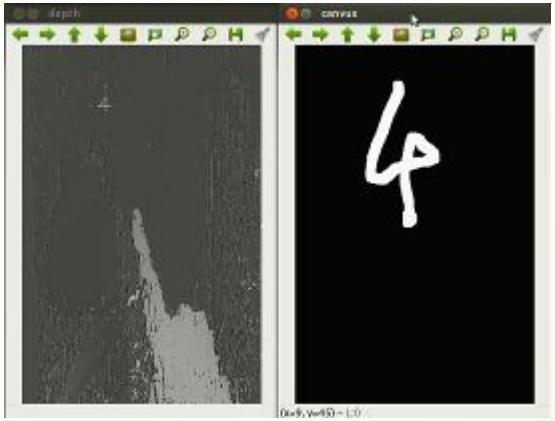
1



2

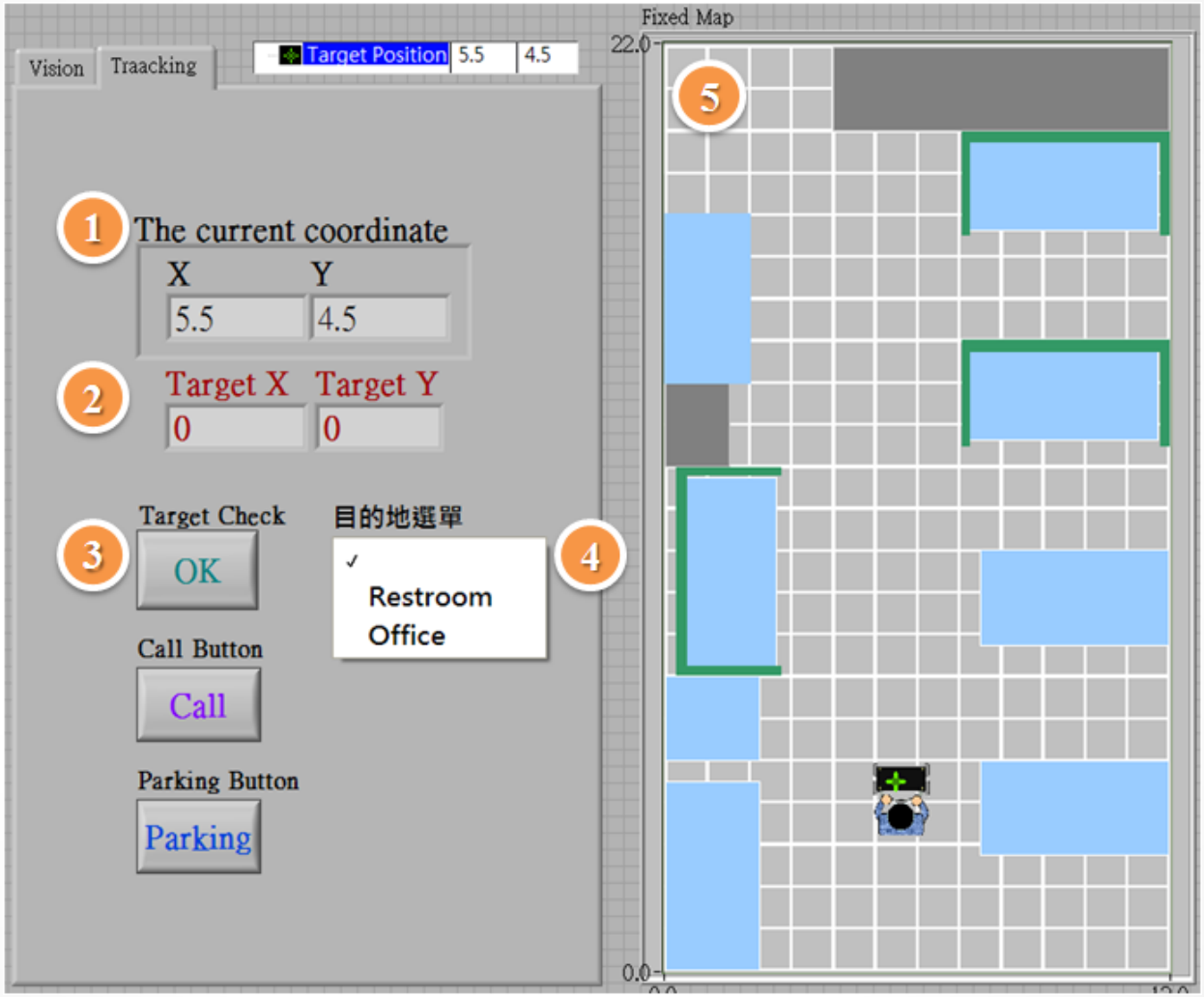


3



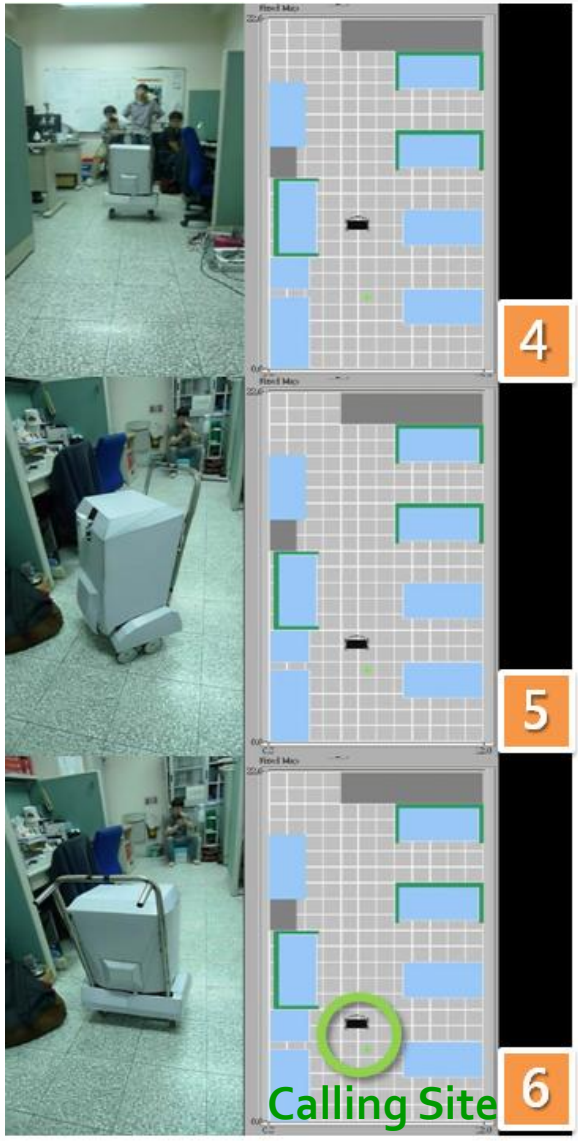
4

Experimental Results – Monitoring Interface

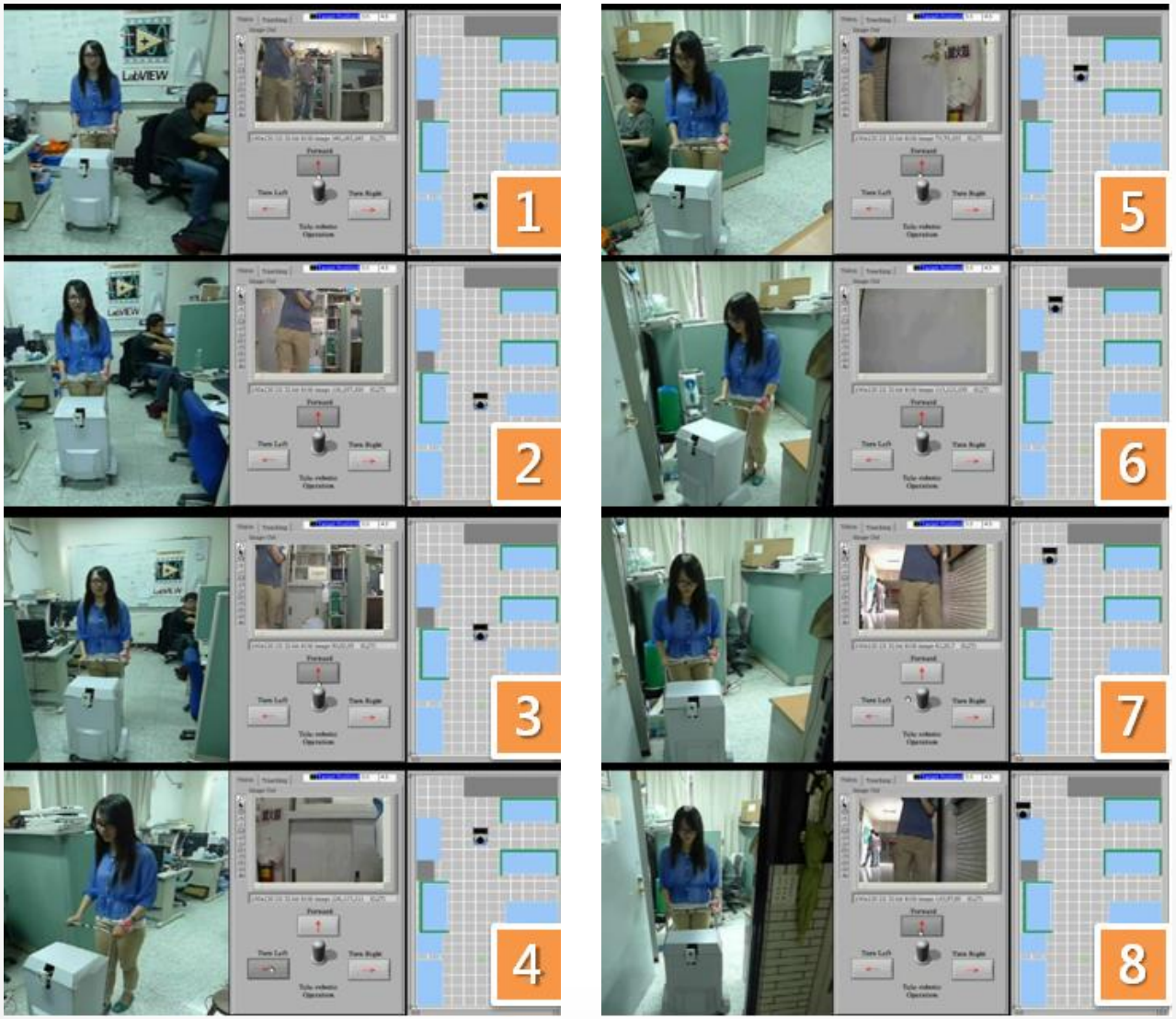


1. Robot Coordinate
2. Target Coordinate
3. Feature Selection
4. Target List
5. Map

Experimental Results – Call-and-come Service

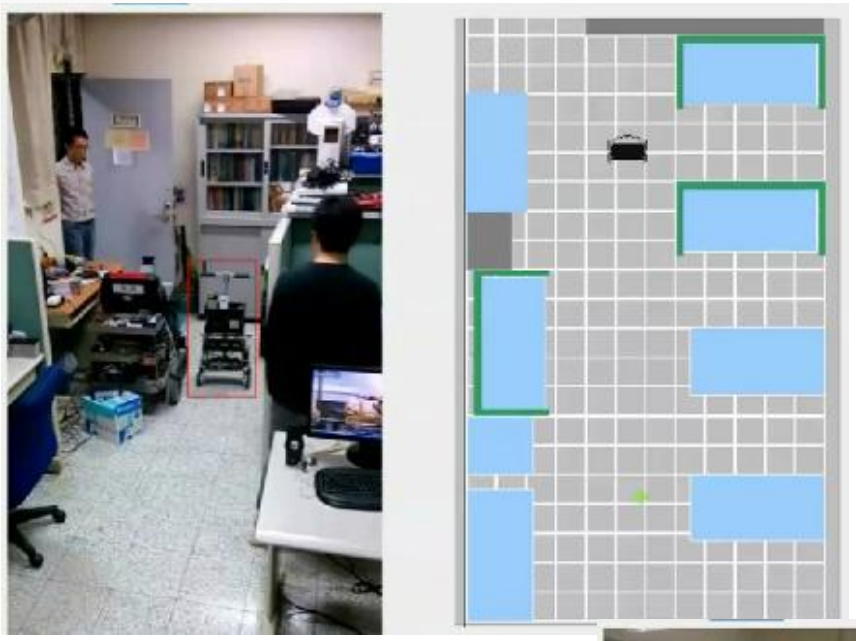


Experimental Results – Navigation Assistance

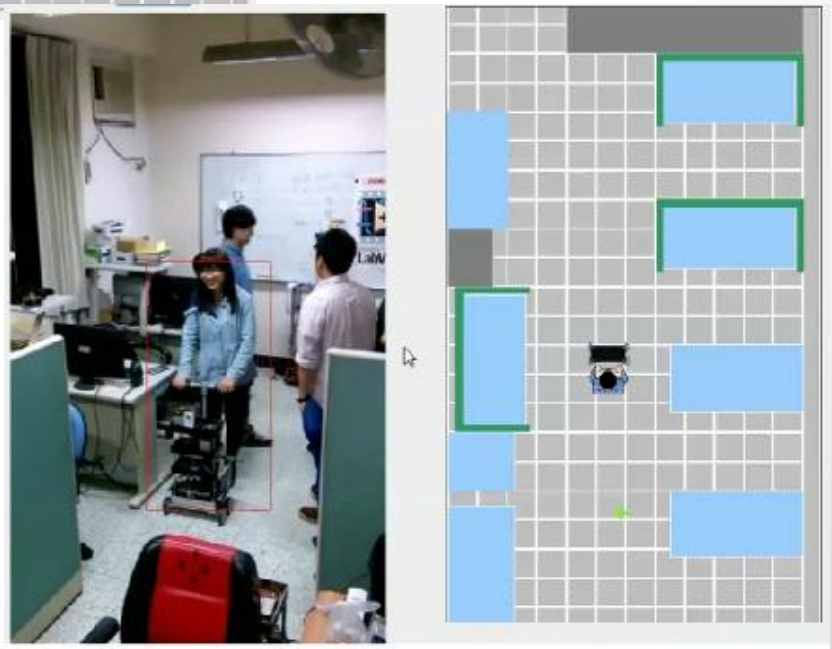


Experimental Results –Vision-based Monitoring

Robot Monitoring

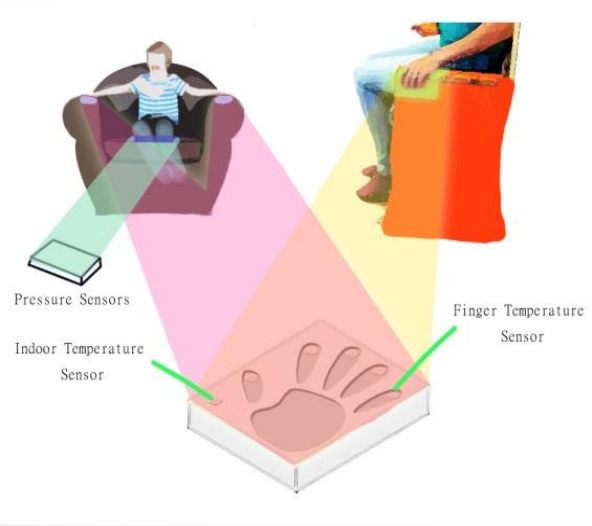


User-robot Monitoring



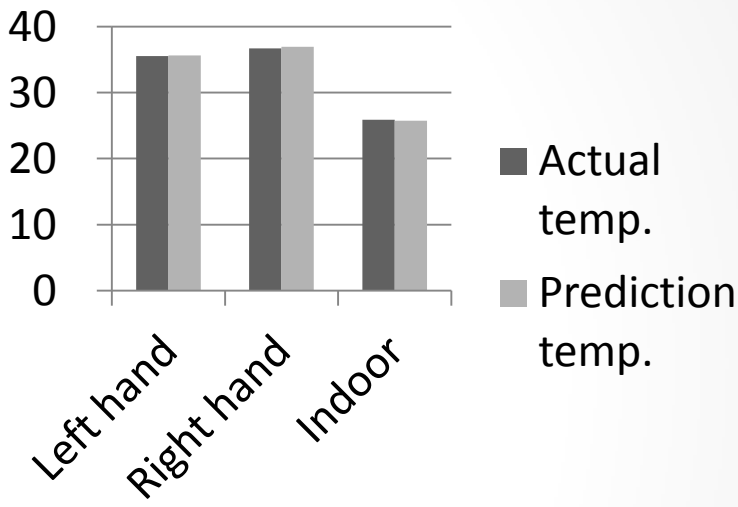
Body Monitoring and Cognitive Support

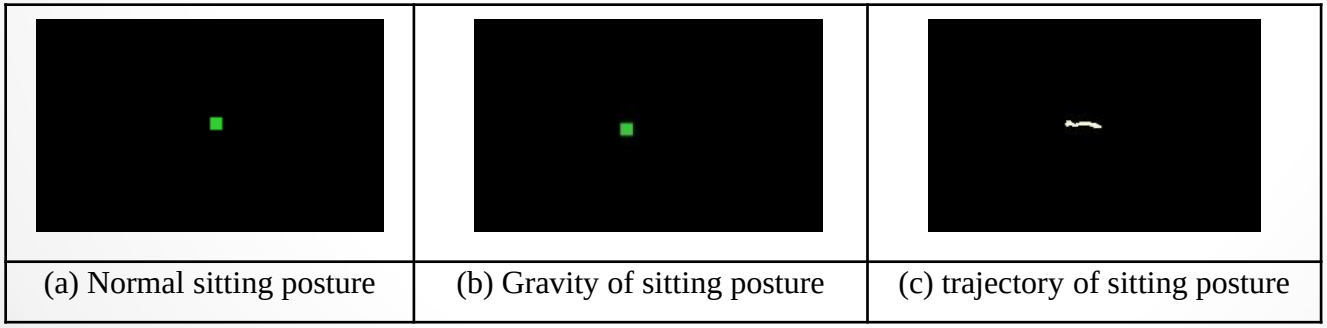
- Body information monitoring module
  - The proposed body information monitoring module is composed of infrared temperature sensors and Wii Fit sensor.
  - The measured fingertip temperatures and body weight are used to keep their body temperature pace with ambient temperature and to evaluate the body functions.



Experimental – Body Information Monitoring

No.	Left hand fingertip average temp.	Right hand fingertip average temp.	Indoor average temp.
1	23.29	24.91	24.67
2	25.31	27.10	23.12
3	31.67	34.89	28.23
4	36.96	37.82	27.47
5	36.17	36.00	28.88
6	37.44	38.20	31.55
7	38.45	37.73	30.15
8	39.62	40.27	30.64
9	37.35	40.00	30.80
10	35.64	35.17	29.90

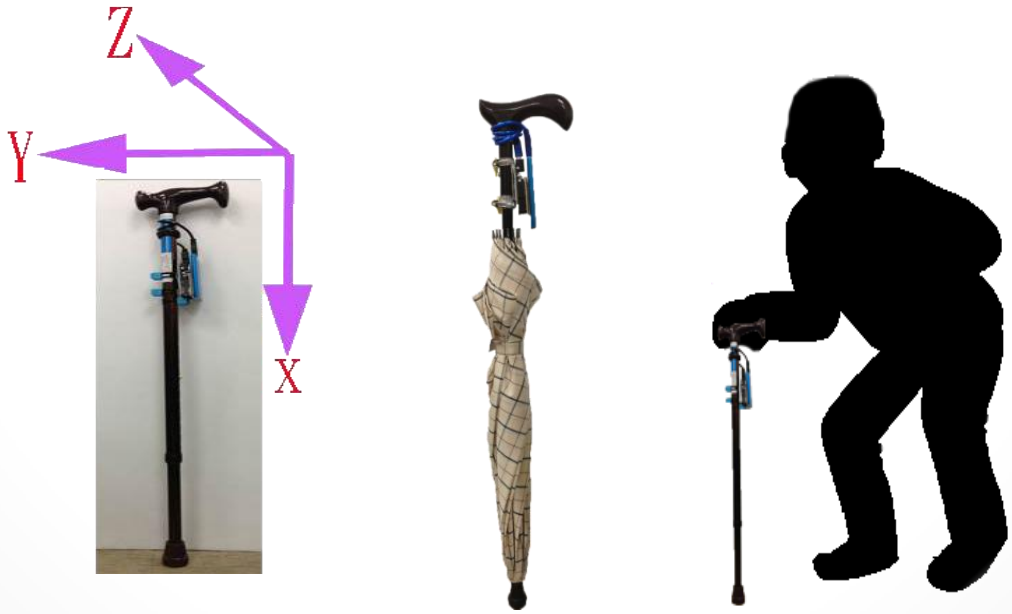




(a) Normal sitting posture | (b) Gravity of sitting posture | (c) trajectory of sitting posture

Intelligent Cane and Umbrella

- The devised intelligent cane consists of Arduino microcontroller board and ADXL345 tri-axial accelerometers.
- The detected accelerometer signals were transmitted to the smart phone for gait patterns identification by Bluetooth.

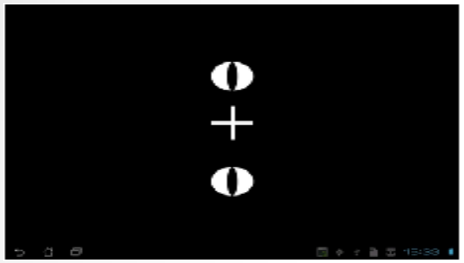


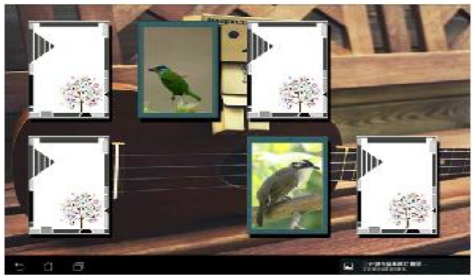
Gait Patterns

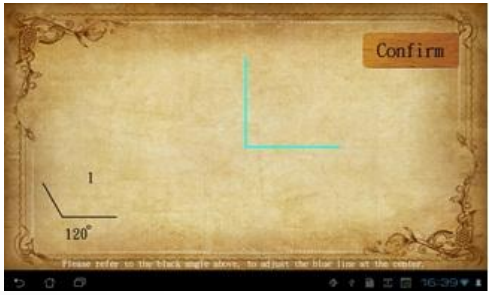
- 11 subjects (4 female and 7 male) with average height 170±8.7cm.

using cane		activity		
		normal	tilted to the left	tilted to the left (trembling)
result	normal	31	3	0
	warning	2	29	4
	abnormal	0	1	29
accuracy		93.9%	87.8%	87.8%
average		89.8%		

Cognitive Examination System







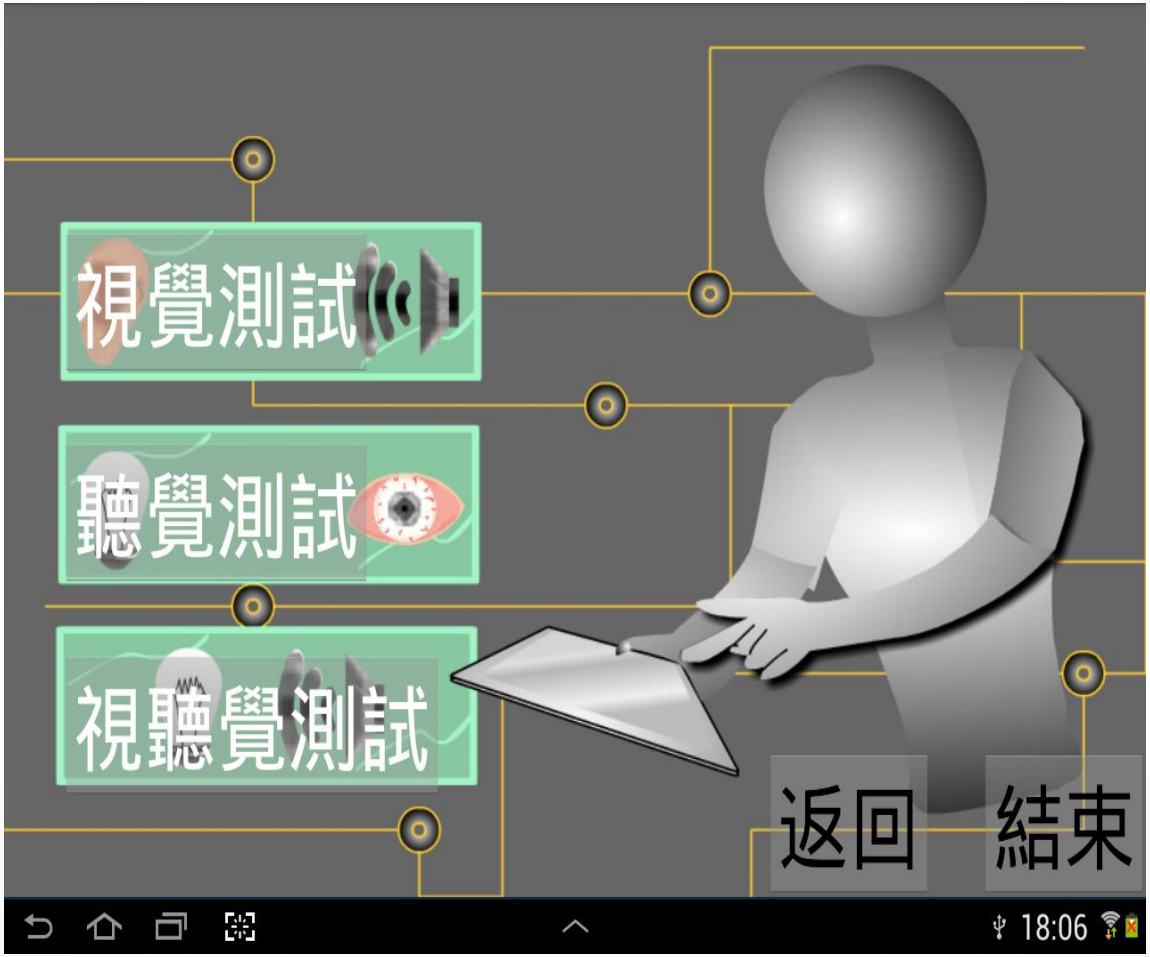
Visual, auditory, audiovisual, card matching, hit the Jerry mouse, angle

Interface of Cognitive Examination System

Four different languages

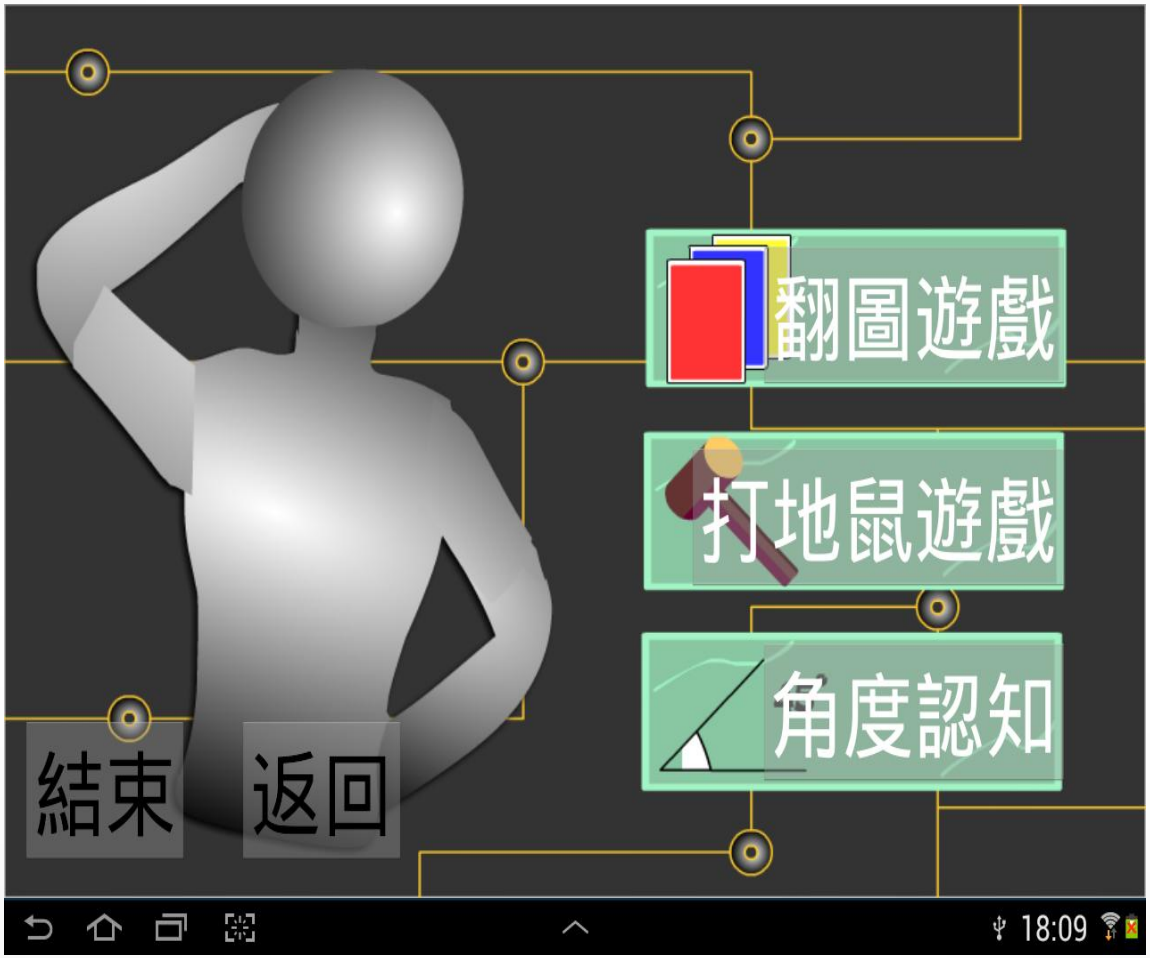
Function Menu : Cognitive Examination or Games

Cognitive Examinations Menu



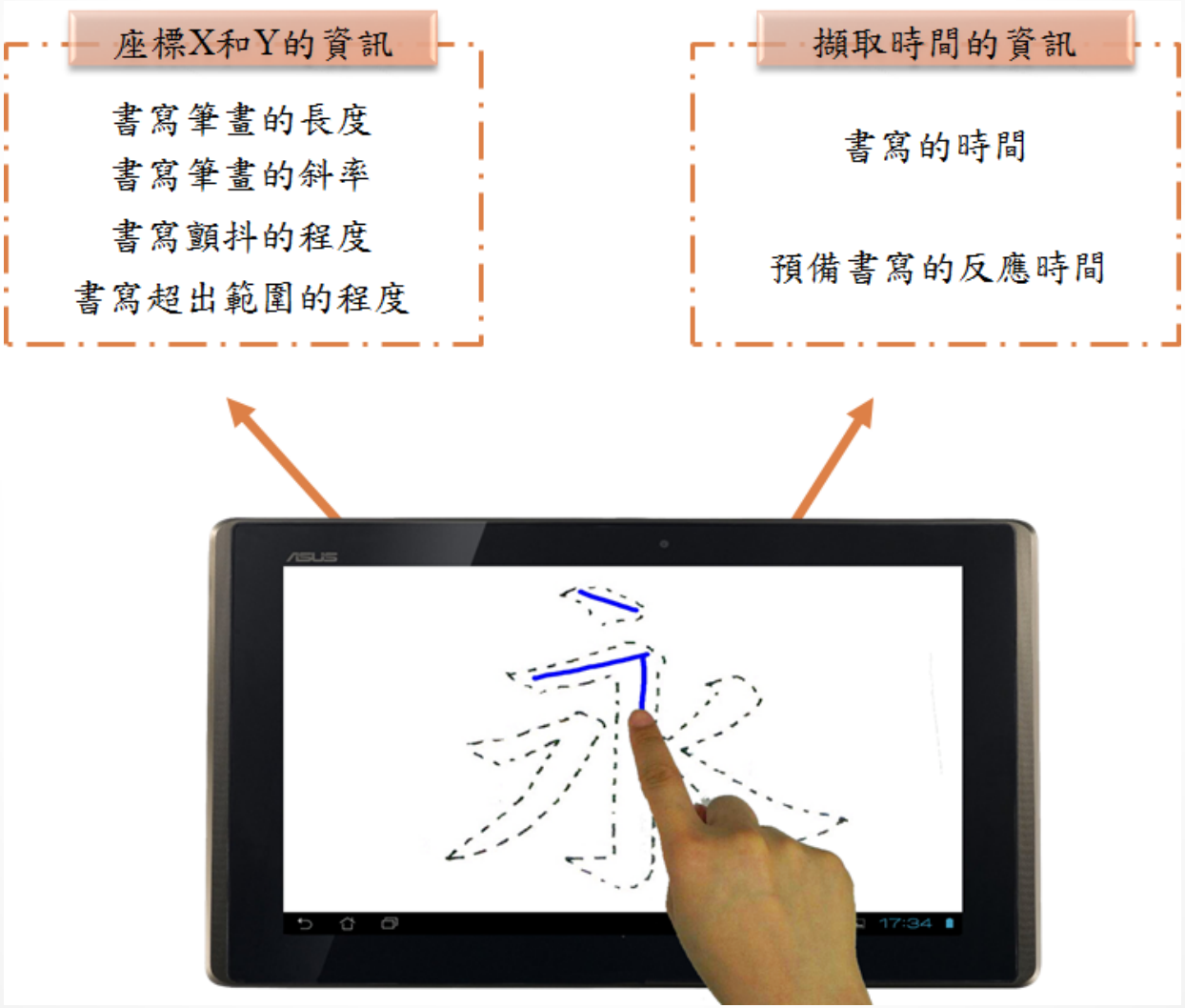
Cognitive examinations include: visual, auditory, and audiovisual

Games Menu

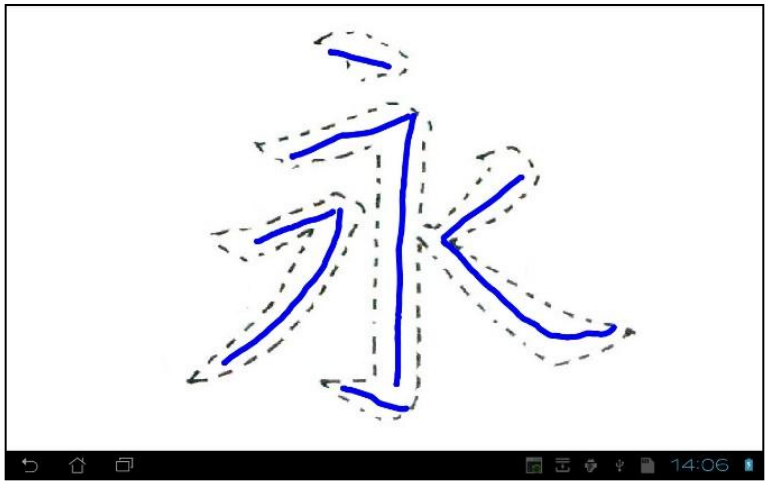


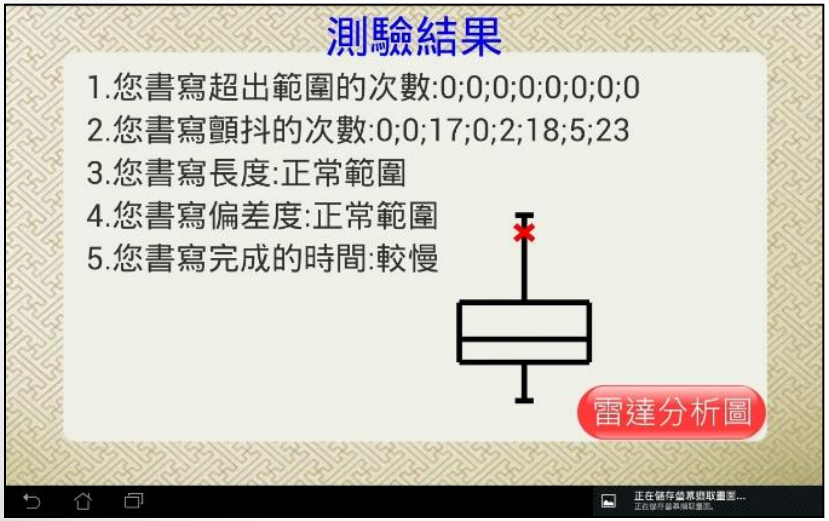
Games include: card matching, hit the Jerry mouse, and angle

Interface of Yong-word Test



Results from Yong-word Test





High Utility Pattern Mining

TID \ ITEM	a	b	c	d	e	Trans. Utility
T_1	2	2	0	0	0	34
T_2	3	0	12	4	2	88
T_3	0	0	15	0	3	66
T_4	4	0	0	0	0	8
T_5	0	10	0	8	9	277
T_6	0	7	3	0	4	142
T_7	1	0	2	0	1	15
T_8	2	0	0	1	3	33

ITEM	PROFIT($) (per unit)
a	2
b	15
c	3
d	8
e	7

tu (Transaction utility)

$$tu(\mathrm{Tq}) = \sum_{ip \in Tq} u(ip, \mathrm{Tq})$$

$tu(T_1)= u(\ a,T_1) + u(\ b,\ T_1)=4+30=34.$

twu (Transaction-weighted utilization)

$$twu(\mathrm{X}) = \sum_{X \in Tq \in D} tu(\mathrm{Tq})$$

$twu(ac)=tu(T_2)+tu(T_7)=88+15=103.$

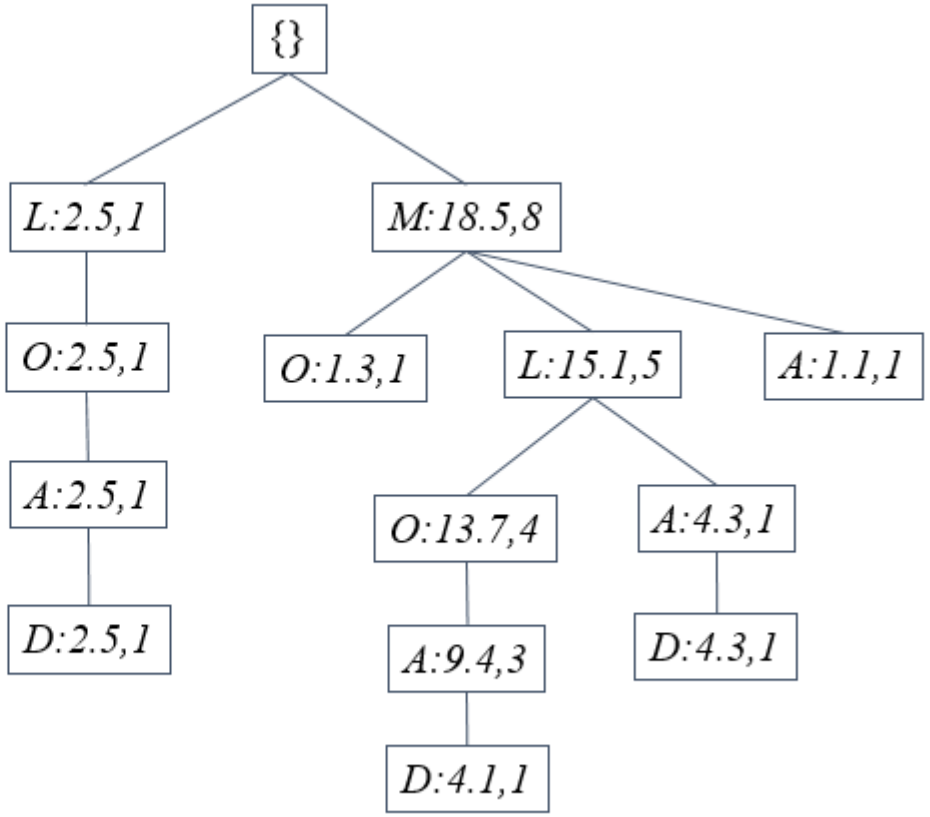
Subjects for Yong-word Test

	Subjects
Age	77.3±8.4[66-87]
MMSE	18.0±4.9
Female	5
Male	4

Tree for High Utility Pattern Mining

Header Table

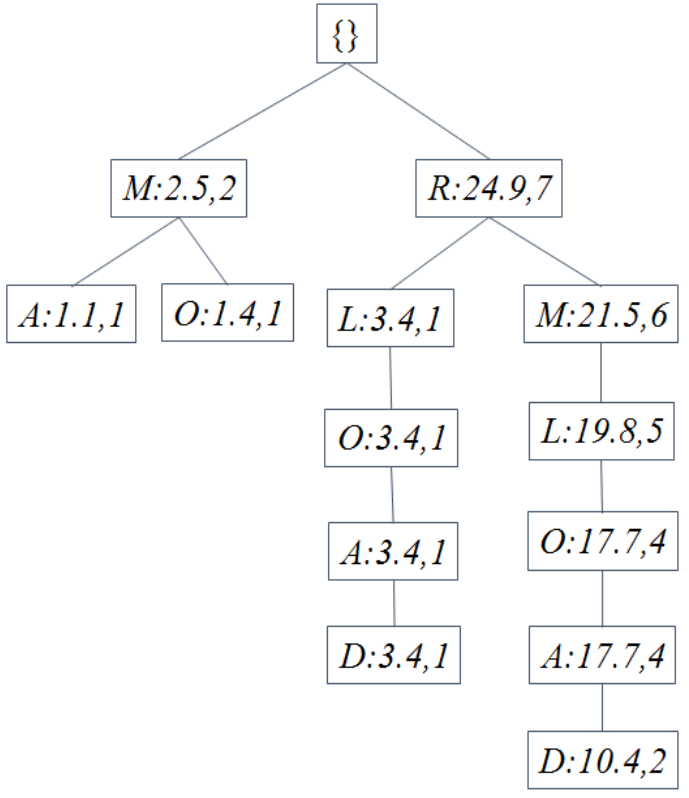
Item	twu	tf
M	18.5	8
L	17.6	6
O	17.5	6
A	17.3	6
D	10.9	3



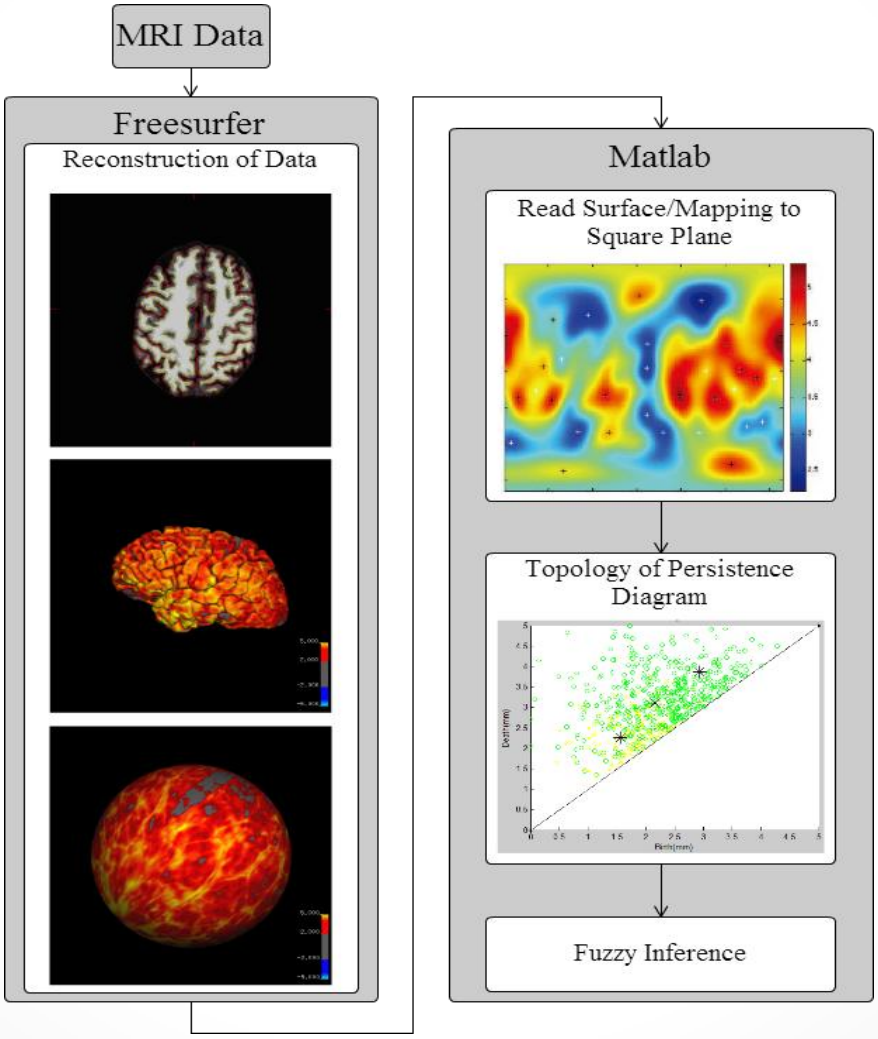
Tree for High Utility Pattern Mining from Yong-word Test

Header Table

Item	twu	tf
R	24.9	7
M	24	8
L	23.2	6
O	22.5	6
A	22.2	6
D	13.8	3



Dementia Risk



Evaluation of the System

ID	Gender	Age	Symptom	2-inputs F.S.	3-inputs F.S.	2-inputs F.S. Result	3-inputs F.S. Result
1	F	75	MCI	0.6527	0.6527	TP	TP
2	M	86	MCI	0.6901	0.7137	TP	TP
3	F	75	MCI	0.4122	0.6299	FN	TP
4	F	26	SCZ	0.5618	0.5962	FP	FP
5	F	38	SCZ	0.2154	0.2154	FN	FN
6	M	21	SCZ	0.2195	0.2195	FN	FN
7	F	67	AAMI	0.6706	0.6826	TP	TP
8	M	63	AAMI	0.6556	0.6556	TP	TP
9	F	44	Healthy	0.2827	0.2894	TN	TN
10	M	43	Healthy	0.2421	0.2421	TN	TN
11	F	19	Healthy	0.2069	0.2115	TN	TN
12	F	19	Healthy	0.2069	0.2069	TN	TN
13	M	26	Healthy	0.2387	0.2441	TN	TN
14	F	72	MCI	0.3484	0.6413	FN	TP

Evaluation of the System

Classification Trials		
	2-input System	3-input System
True negative (TN)	5	5
True positive (TP)	4	6
False positive (FP)	1	1
False negative (FN)	4	2
Total	14	14
Accuracy	0.6429	0.7857
Balanced Accuracy	0.6667	0.7917
Sensitivity	0.5	0.75
Specificity	0.8333	0.8333
PPV	0.8	0.8571
NPV	0.5556	0.7143
Likelihood ratio	1.6667	3.3333

Conclusions

- This research aims to provide necessary functions for next generation nursing home system
- We have effectively integrated three major enabling technologies
  - Robotic assistance and living aid,
  - environmental monitoring and HCI,
  - Body monitoring and cognitive support.
- More experiments on actual deployment in real environment will be under way

Thank you !