Introduction of Bio-Robotics and Human-Mechatronics Laboratory

Bio-Robotics and Human-Mechatronics Laboratory
Graduate School of Information, Production and Systems, Waseda University
http://www.waseda.jp/sem-matsumaru/

Takafumi MATSUMARU
http://www.aoni.waseda.jp/matsumaru/
matsumaru@aoni.waseda.jp

2014.02 Peking University and Beijing Institute of Technology, Beijing, China

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Biographical Information

Ichiro Kato
1926-1994

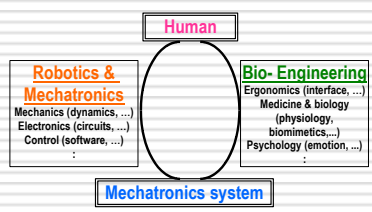
- 1985 B.S., Mechanical Engineering, Waseda University
  "Development of articulated manipulator aiming at force control"
  (Supervised by late Prof. I.Kato)
- 1987 M.S., Mechanical Engineering, Waseda University
  "Basic theory of multi d.o.f. compliance control on articulated manipulator"
  (Supervised by late Prof. I.Kato)
- 1987-99 Corporate Research & Development Center, Toshiba Corporation
  - Research on robots for specialized operations
  - Developing mechatronics systems using robotic technologies

TOSHIBA
Leading Innovation

- 1998 Ph.D., Mechanical Engineering, Waseda University
  "Research on structure and control of working robot in a narrow space"
  (supervised by Prof. S.Sugano)
- 1999-2010 Associated Professor, Shizuoka University
  - Education and Research on Bio-Robotics and Human-Mechatronics
  - Invited Professor (2003). LSC - CNRS, Evry France, Visiting Fellow (2002). Shizuoka Industrial Research Institute, Shizuoka Japan, etc.
- 2010- Professor, Waseda University
  - Research and Education on Bio-Robotics and Human-Mechatronics

Bio-Robotics and Human-Mechatronics Laboratory

- Various themes between human and mechatronics systems (robots and other systems)
- To make mechanical systems more friendly / useful for users
- Developing new functions and producing real-world systems
- Integrating various knowledge and technologies into systems (selection / combination are based on engineering sense)
- Work on elemental technologies by ourselves if desired



Better interaction / relationship between human and robots

Study subject

- Remote Operation System of Mobile Robot
  - Combination Control of Manual Operation and Autonomous Behavior
  - Environmental Map around remote robot --- Line&Hollow / Cell&Hollow
  - Operational Interface --- J/S, Eye-gaze, HMD+gaze, Voice, Touch screen
- Preliminary-Announcement of Robot's Intention
  - Method and Apparatus to indicate Direction and Speed --- 4 kinds / 2 types
  - Comparing Display Announcement with Voice Announcement
- Form and Movement of Human-Synergetic Robot
  - Informative Kinesics on Human-Machine System --- design theory
  - Informative Motion as Motion Media to incorporate information
- Interaction with Human-Symbiotic Robot
  - Step-on Interface (SOI) --- bilateral interface via projected screen
  - Friendly Amusing Mobile (FAM) --- playing "light" tag
- Measurement and Analysis of Human Movement
  - Lifting of Heavy Weight --- movement evaluation and optimal posture
- Systematic and Effective Learning Method on Mechatronics
  - Using LEGO-Mindstorm and Sony-AIBO

Study subject

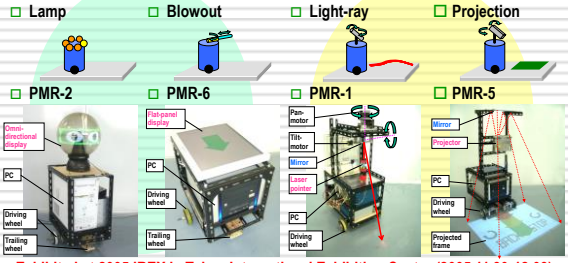
- Remote Operation System of Mobile Robot
  - Combination Control of Manual Operation and Autonomous Behavior
  - Environmental Map around remote robot --- Line&Hollow / Cell&Hollow
  - Operational Interface --- J/S, Eye-gaze, HMD+gaze, Voice, Touch screen
- Preliminary-Announcement of Robot's Intention
  - Method and Apparatus to indicate Direction and Speed --- 4 kinds / 2 types
  - Comparing Display Announcement with Voice Announcement
- Form and Movement of Human-Synergetic Robot
  - Informative Kinesics on Human-Machine System --- design theory
  - Informative Motion as Motion Media to incorporate information
- Interaction with Human-Symbiotic Robot
  - Step-on Interface (SOI) --- bilateral interface via projected screen
  - Friendly Amusing Mobile (FAM) --- playing "light" tag
- Measurement and Analysis of Human Movement
  - Lifting of Heavy Weight --- movement evaluation and optimal posture
- Systematic and Effective Learning Method on Mechatronics
  - Using LEGO-Mindstorm and Sony-AIBO

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Preliminary-Announcement of Robot's Intention

- Intention declaration function
  - Difficult to estimate robot's function/ability/operation by appearance
  - Danger on contact and collision
  - ⇨ preliminary-announcement = direction of movement and speed of movement
- State at some future time
  - Lamp
  - Blowout
- Continuously from present to future time
  - Light-ray
  - Projection

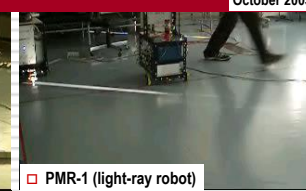


Exhibited at 2005 iREX in Tokyo International Exhibition Center (2005.11.30-12.03)

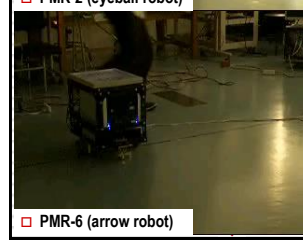
Demonstration

October 2005

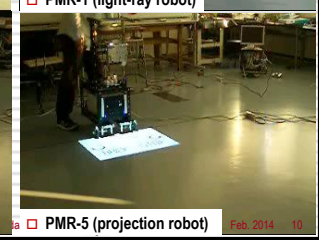
PMR-2 (eyeball robot)



PMR-1 (light-ray robot)



PMR-6 (arrow robot)



PMR-5 (projection robot)

PMR-5R

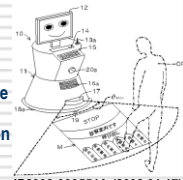
March 2007

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Step-On Interface, SOI, for human-robot interaction

- **Step-On Interface (SOI) function**
  - Projected screen is used as a bilateral interface
    - Not only present information from equipment to user
    - But also deliver instruction from user to equipment
  - Projector displays a direction screen on a surface
  - Sensor (2D range scanner) detects and measures the user's stepping to specify the selected button

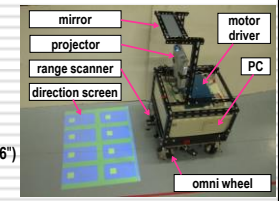


JP2008-006551A (2008.01.17)

- **Features**
  - Hands-free
    --- elderly, physically challenged, and users whose hands are full
  - Anywhere
    --- without disturbing others and in noisy environment
  - No special devices are needed
    --- user's own foot or stick (cane)
  - Requires little preliminary preparation or special setup --- by projection
  - Can use figures / pictures in addition to letters
    --- language-independent, possible for beginners and non-native speakers
  - Functions are easy to design, setup and change --- in software

Human-Friendly Amusing Mobile Robot, HFAMRO-1

- **Omni-dir. mobile platform**
  - Omni-wheels (4)
  - HD-geared DC-motor (4)
- **Step-On Interface (SOI)**
  - Projector
    - Min. distance: 1200mm
    - Screen size: W730 x D550mm (36")
  - Mirror
    - W225 x D125 mm
  - Range scanner
    - Area: 240deg / 682step (0.35deg/step)
    - Distance: 20 - 4095mm
    - PC acquires data every 100ms

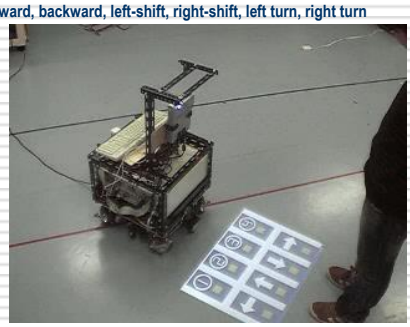


Size	W450 - D450 - H960 mm
Weight	46.7 kg
Speed	max. 0.22m/s, 0.87rad/s
PS	AC100V

Exhibited at 2007 iREX in Tokyo International Exhibition Center (2007.11.28-12.01)

HFAMRO-1 movement (1)

- **Basic movement**
  - Forward, backward, left-shift, right-shift, left turn, right turn

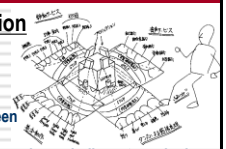


March 2007

Outline

Friendly Amusing Mobile (FAM) function

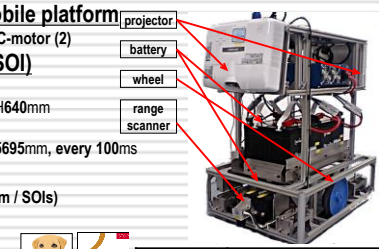
- **FAM (Friendly Amusing Mobile) function**
  - Robots dynamically interact with users
- **Play tag**
  - Play tag with "light", similar to 'shadow' tag
  - User pursues robot and steps on button on screen
  - Robot responds as to the button
    --- by playing game, providing with information, moving to indicate 'emotion'...



- **Game: step on animal's tail**
  - Scenario
    - Animal's head and tail are displayed
    - Moves characteristically, cocking head and wagging tail
    - Stop, cry out, and show anger, when caught up / stepped
  - Technical aspect
    - Self-contained mobile robot, independent without movement restriction
    - Playing tag with "light" function

Human-Friendly Amusing Mobile Robot, HFAMRO-2

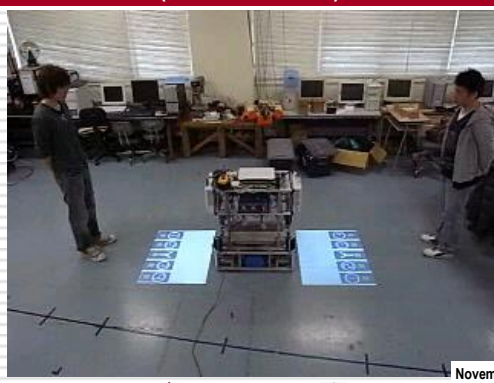
- **Two-wheel drive mobile platform**
  - D200-wheel (2), DC-motor (2)
- **Step-On Interface (SOI)**
  - Projector
    - L560mm, W850 x H640mm
  - Range scanner
    - 0.35/240deg, 20 - 5695mm, every 100ms
- **Power source**
  - Battery (mobile platform / SOIs)
  - External AC100V cable
- **Application**
  - Stepping animal tail
  - Stamping bomb fuse
  - Stepping target footprint



Features	Specifications
Size	L700 - W520 - H810 mm
Weight	120 kg
Max. speed	1.0 m/s, 360 deg/s
Power source	Battery (40 min) / AC100V

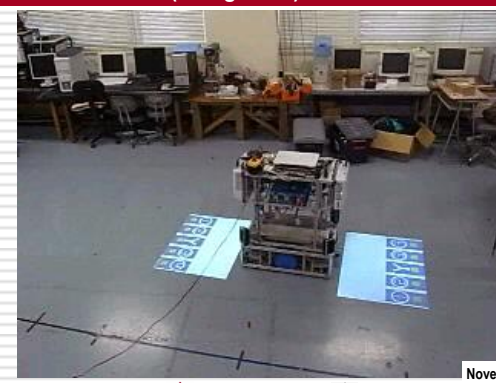
Exhibited at 2009 iREX in Tokyo International Exhibition Center (2009.11.25-11.28)

Basic movement (from both sides)



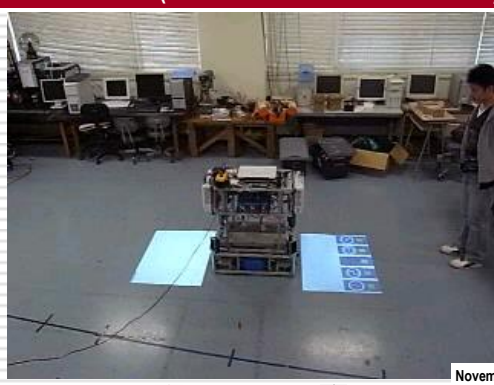
November 2009

Basic movement (using stick)



November 2009

Basic movement (work with announcement func.)



November 2009

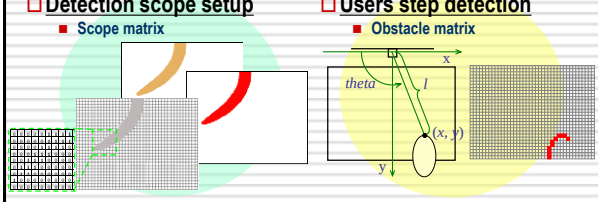
To realize playing tag (1) Cutoff animation

- Cutoff animation
  - Tail
    - Landscape-oriented BMP image arranging 14 pictures showing instantaneous states
    - Changing appointed place using a timer

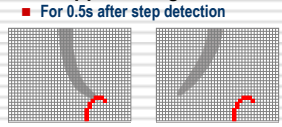
  - Head
    - Ordinary expression with cocking while moving
    - Anger expression with loud cry when stepped

To realize playing tag (2) Image stepped-on recognition

- Detection scope setup
  - Scope matrix
- Users step detection
  - Obstacle matrix

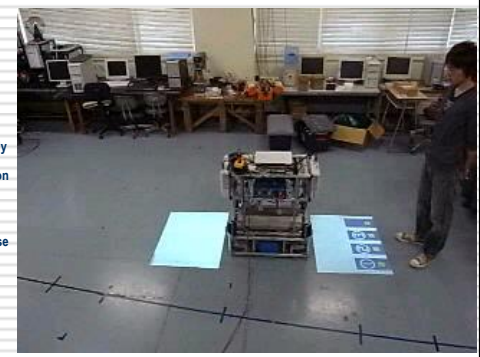


- Tail stepped recognition
  - For 0.5s after step detection



Stepping on animal's tail (dog – fast)

- Animal selection
  - Dog / Cat / Pig
- Start moving
  - Cocking head
  - Wagging tail
  - Panting
- Catch up with / step on tail
  - Stop immediately
  - Loud cry
  - Anger expression
- Removed
  - Start again
- Kept for a while
  - Shake itself loose
- Get away
  - Turn around
  - Call for
- Come close
  - Start again
- Stop button
  - Initial screen



November 2009

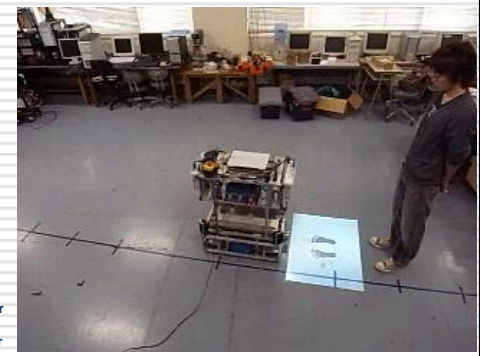
Stamping bomb fuse (success)

- Fuse
  - Spark at end
  - Swinging
- User
  - Stamp on spark
  - 15 times in 45 s
- Moves
  - Playing Background music
  - Showing time left / remaining num. to stamp
- Crash sound
  - When hits spark
- As time passes
  - Moves faster
  - Fuse shorter
  - Pick up tempo

November 2009

Stepping footmark (gait training)

- Make trainee
  - Strong desire to commit rehabilitation of walking
- Initial screen
  - Two marks of both feet
- Session starts
  - User puts feet
  - Makes sound, move forward, display mark
- Sequential presentation
  - User puts foot
  - Makes sound, move forward, display the other
- Get away
  - Sound to call for



November 2009

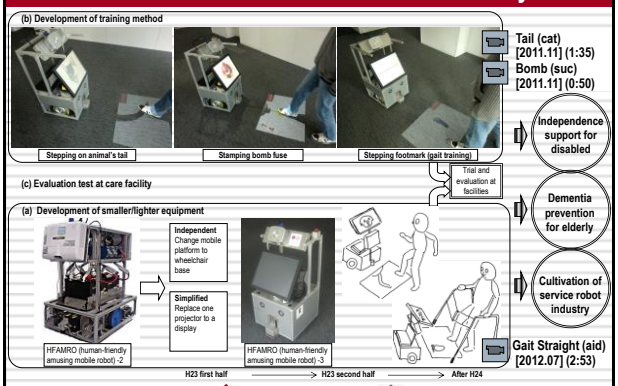
Outline

Play "light" tag

- Requirement
  - Sense --- Visual contact
  - Brain --- Cognition and judgment
  - Body --- Mobility
- Expected effect
  - Maintenance
  - Training
  - Recovery

  → Human physical function and cognitive abilities
- Foot-eye coordination training → Walking trainer mobile robot
  - Stagnation in training due to difficulty/exhaustion relieved
    - by introducing game element
    - to motivate trainees and maintain their interests
  - Safety for "fall down" in trainee
    1. Smaller/lighter equipment, for trainee using walker
    2. Except mobility → specialized in upper body exercise

HFAMRO-3: Function maintenance and recovery exercis



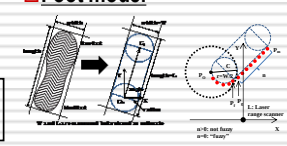
Walking trainer with customizable trajectory design

- System structure

  Foot Detection
  Define and calculate position and direction of a foot

  Robot calculation
  Calculate position and direction of mobile robot

  1. Trajectory designer <Teaching> Use mobile robot to track and record tutor's steps and walking trajectory using laser range scanner.
  2. Trajectory viewer Display recorded trajectory graphically and calculate data for analyzing on a computer.
  3. Mobile walking trainer <Training> Apply data calculated along trajectory on mobile robot for trainee's steps and evaluate training status.
- Foot model

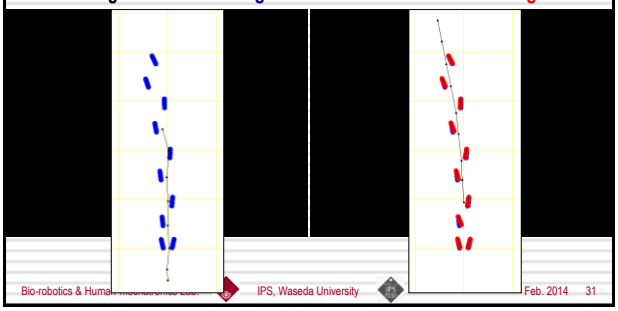


- Features
  - Actual walking feeling for trainee
  - Can design trajectory suitable for different patient
    - A tutor walks and robot follows, applying into walking training

Walking training test (1) Straight-line

July 2012

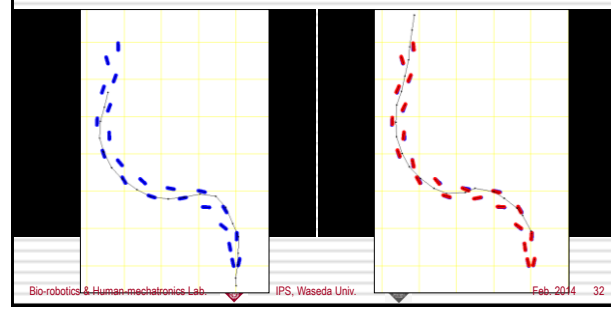
- Teaching
  - Tutor's feet sequence detected in *Trajectory Designer* while teaching
- Training
  - Trainee's feet sequence detected in *Mobile Walking Trainer* while training



Walking training test (2) S-shape

July 2012

- Teaching
  - Tutor's feet sequence detected in *Trajectory Designer* while teaching
- Training
  - Trainee's feet sequence detected in *Mobile Walking Trainer* while training

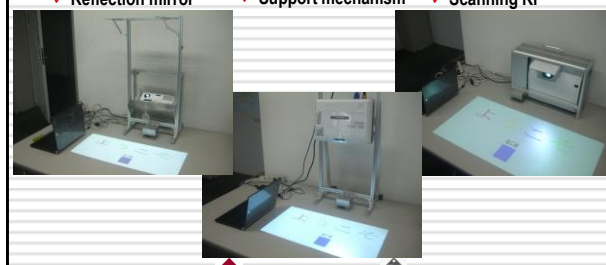


Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Image-projective Desktop Arm Trainer, IDAT

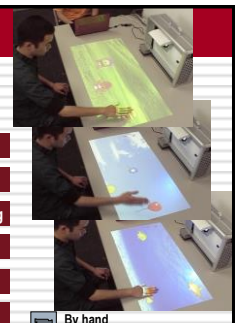
- IDAT-1
  - Reflection type
  - W365-D470-H800mm
  - 7.5kg (main body)
  - ✓ Reflection mirror
- IDAT-2
  - Direct type
  - W380-D380-H680mm
  - 8.5kg (main body)
  - ✓ Support mechanism
- IDAT-3
  - Built-in type
  - W500-D160-H360mm
  - 10.2kg (main body)
  - ✓ Scanning RF



Procedure for training

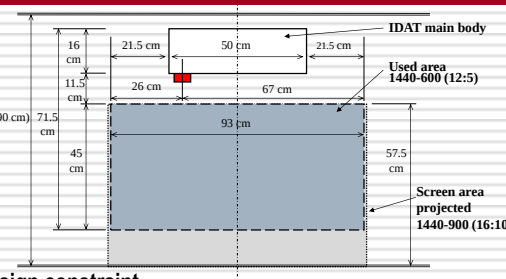
- Parameter setting
  - Sufficient WL
  - Adjusted
  - Even with both
- Training
  - To pat object
- Result
  - Stimulate will
  - Rouse challenge

Start
Welcome Screen
Game Time Setting
Object Speed Setting
Object Number Setting
Setting Confirmation
Mole Patting
Balloon Breaking
Fish Catching
Result Screen
End



By hand [2012.06] (2:45)
By hand keeping on screen [2012.06] (2:45)
By hand having pause [2012.06] (3:00)
By hammer [2012.06] (2:41)

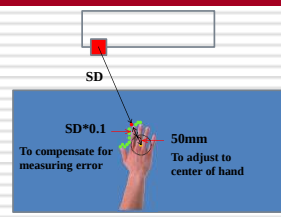
Installation condition and screen size



- Design constraint
  - Can be installed on *standard 90-centimeter-wide* desk
  - *Used area* is in *reachable* depth and width *by one hand*
  - *Bottom area* to put elbows/opposite hand to support oneself

Collision detection

- Hand location
  - Nearest data
  - Correction
    - To compensate for measuring error
    - To adjust to center of hand
- Collision detection
  - Trainee's hand with object
    - Whether hand location is on *hit zone* or not
  - Hit zone
    - Set on object (texture)
    - Difficulty adjustable by changing size



Outline

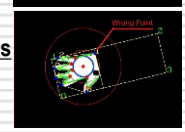
Hand/Fingertips/Touch Detection

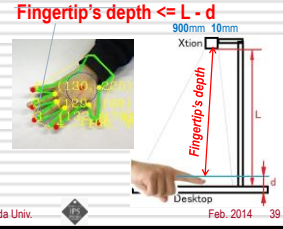
- Procedure: RGB-D (Xtion)
  1. Initialization of Xtion
  2. Set Background
  3. Hand Detection
  4. Fingertips Detection
  5. Touch Event Detection

  Application

- Hand
- Fingertips
- Touch

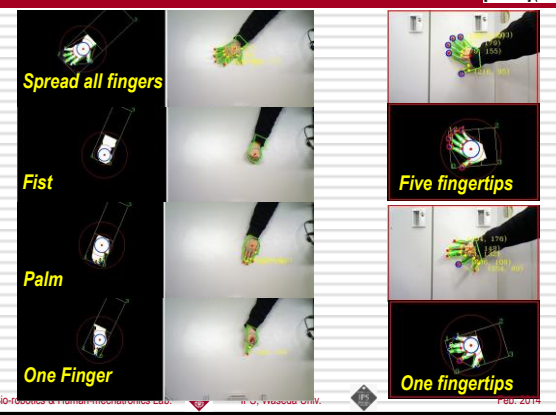
Fingertip's depth <= L - d





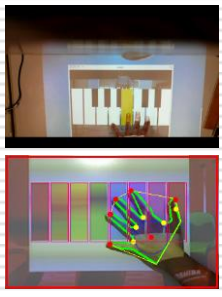
Touch event detection

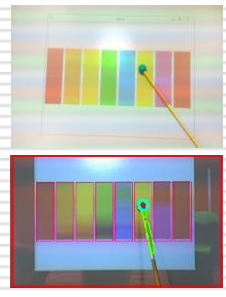
Finger touch [2013.01] (1:12)



Hand/mallet distinction + Touch speed detection

- Virtual Piano
- Virtual Xylophone





Virtual Piano [2013.10] (0:57)

Virtual Xylophone [2013.10] (0:52)

Demonstration

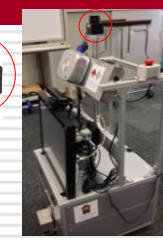
Piano&Xylophone [2013.02] (3:00)

Submitted to ACM/IEEE HRI 2014 video session, but rejected…!!!

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Mobile robot companion



- Human detection
  - → To solve the detection range problem
  - using laser range scanner
    - Data points clustering
    - Human position (ellipse fitting + Kalman filter)
- Human following
  - → To solve the unlimited robot speed problem
  - with adaptive acceleration of robot movement
    - Speed stages: 1) increasing, 2) saturation, 3) decreasing
  - with obstacle avoidance
    - Temporary target point
- Remote operation
  - → Mobile phone control
  - Java + Socket programming

Human detection

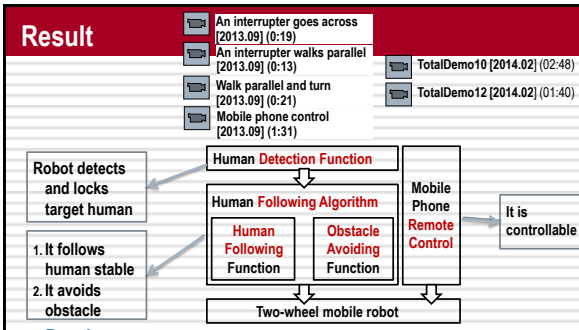
Result 1: rotating, walking, interrupted

Result 2: embrace

Shortcoming: once target lost, …

- Result:
  detection function reaches our needs.
- Shortcoming
  limited search area to lock human

Result



- Result:
  Control strategy proposed (detection function, following algorithm, remote control) can assists a mobile robot to follow human.
- Short coming:
  Data by single laser scanner is limited (only one surface depth)

Outline

- Introduction
  - Biographical Information, BR&HM Laboratory
- Recent activities
  - Preliminary-Announcement of Robot's Intention
    - To indicate Direction and Speed, Comparing Display with Voice
  - Step-On Interface (SOI)
    - Bilateral Interaction via Projected Screen, Mobile Robot Operation
  - Friendly Amusing Mobile (FAM) function
    - Playing "Light" Tag, Image stepping-on Recognition
  - Walking Trainer Mobile Robot System
    - Trainee with Walker/Crutch, Customizable Trajectory Design
  - Image-projective Desktop Arm Trainer (IDAT)
    - Hand-eye coordination Training, Hardware/Software Design
  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
  - Mobile Robot Companion
    - Human Detection + Human Following + Remote Operation
- Closing remarks

Robotics / Humanics

- Various robots are announced in a big event and reported widely
- However, what will robots provide after losing such extra-ordinary?
- Robotics research and development lead us to consider humanity to confirm human dignity
- Learn about ourselves while implementing what we think is required and helpful for people in a robot
- We desire higher level of human nature and we cultivate enriched humanness while robotics research and development
- Robotics is Humanics (from engineering viewpoint)

Introduction of Bio-Robotics and Human-Mechatronics Laboratory

Bio-Robotics and Human-Mechatronics Laboratory
Graduate School of Information, Production and Systems, Waseda University
http://www.waseda.jp/sem-matsumaru/

Takafumi MATSUMARU
http://www.aoni.waseda.jp/matsumaru/
matsumaru@aoni.waseda.jp

2014.02 Peking University and Beijing Institute of Technology, Beijing, China