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.aoni.waseda.jp/matsumaru/

Takafumi MATSUMARU

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

Training Trailer 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/Fingertip/Touch Detection, Virtual Keyboard/Xylophone

Mobile Robot Companion

Human Detection + Human Following + Remote Operation

Closing remarks

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: JIS, Eye-gaze, HMD=goes, 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

Interactive Kinetics 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-Mindstorms and Sony-ABD

Closing remarks

Biographical Information

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

1996 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.

2010-2016, Professor, Waseda University
Research and Education on Bio-Robotics and Human-Mechatronics

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

Closing remarks

Bio-Robotics & Human-Mechatronics Laboratory

Graduate School of Information, Production and Systems (IPS), Waseda University

Takafumi MATSUMARU

Professor, Distributed Robotics Laboratory, Waseda University, China

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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: Joystick, Eye-gaze, HMD+gaze, Voice, Touch screen

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    - State at some future time
    - Continuously from present to future time
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    - Informative Kinesics on Human-Machine System — design theory
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Demonstration
- PMR-2 (eyeball robot)
- PMR-5 (projection robot)

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  - Touch Interaction
    - Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone
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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
  - Continuously from present to future time
- Lamp
  - Blowout
  - Light-ray
  - Projection

PMR-5
- March 2007

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

PMR-4 (arrow robot)

PMR-5 (projection robot)

PMR-1 (light-ray robot)
Step-On Interface, SOI, for human-robot interaction

- **Step-On Interface (SOI) function**
  - Projector displays a direction screen on a surface
  - Sensor (2D range scanner) detects and measures the user’s stepping to specify the selected button

- **Features**
  - Hands-free
  - Anywhere
  - User’s own foot or stick
  - Requires little preliminary preparation or special setup
  - Functions are easy to design, setup and change

HFAMRO-1

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

Friendly Amusing Mobile (FAM) function

- **FAM (Friendly Amusing Mobile) function**
  - Play tag
  - Game: step on animal’s tail

Human-Friendly Amusing Mobile Robot, HFAMRO-1

- **Omni-dir. mobile platform**
  - Omni-wheels (4)
  - HD-gear DC-motor (6)

- **Step-On Interface (SOI)**
  - Projector
  - Min. distance: 1200 mm
  - Screen size: W1730 x D550 mm

- **Features**
  - Without disturbing others in and noisy environment
  - No special devices are needed
  - Can use figures/pictures in addition to letters
  - Functions are easy to design, setup and change
  - In software

HFAMRO-2

- **Two-wheel drive mobile platform**
  - DC-motor (2)

- **Step-On Interface (SOI)**
  - Projector
  - L560 mm, W560 x H640 mm
  - Range scanner
  - 0.35-240 deg, 20-5695 mm, every 100 ms

- **Power source**
  - Battery (mobile platform / SOIs)
  - External AC100V cable
Basic movement (from both sides)

Basic movement (using stick)

Basic movement (work with announcement func.)

To realize playing tag (1) Cutoff animation

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

Stepping on animal's tail (dog – fast)
Stamping bomb fuse (success)

- Fuse
  - Spark at end
  - Hanging
- User
  - Stamp on spark
  - 15 times in 45 s
- Moves
  - Playing
  - Background music
  - Slowing time left
  - Remaining
  - to stamp
- Crash sound
  - When hits spark
  - As time passes
- Moves faster
  - Fuse shorter
  - Pick up tempo

Strong desire to

Recovery to motivate trainees and maintain their interests

Bilateral

Stagnation in training due to difficulty/exhaustion relieved

Image

Maintenance Safety for "fall down" in trainee

Actual walking feeling for trainee

Training Body

by introducing Hand/Fingertips/Touch Detection, Virtual Keyboard/Xylophone

A tutor walks and robot follows, applying into walking training

Hand

User puts foot

Sound to call for

Friendly Amusing Mobile (FAM) function

Except mobility

Bio

Two marks of

Moves faster

Showing time left

Fuse shorter

Mobile walking trainer

Playing "Light" Tag, Image stepping

Biographical Information, BR&HM Laboratory

When hits spark

User puts feet

Stamp on spark

Human Detection + Human Following

Walking

Smaller/lighter equipment, for trainee using walker

Trainee Sense

Pick up tempo

Mobile

HFAMRO (human

Stepping footmark gait training)

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

Foot model

Foot detection

Define and calculate position and direction of a foot

Robot calculation

Calculate position and direction of mobile robot

Features

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.

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

Features

1. Actual walking feeling for trainee
2. Can design trajectory suitable for different patient

Closing remarks

November 2009

Bio-statistics & Human-mechatronics Lab. IPS, Waseda University

Feb. 2014 - 20

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

Walking trainer mobile robot

Walking trainer with customizable trajectory design

HFAMRO-3: Function maintenance and recovery exercises

- Development of training method
  - Tail (cat)
  - Bomb (dog)
  - Bump (tiger)
  - Independent support for rehabilitation
  - Demonstration for elderly

- Development of service robot equipment
  - Laser range scanner

- Evaluation test at care facility
  - Physical walking test
  - Independent support for rehabilitation

- Training
  - 27 participants
  - Average age 72.5 years

- Training trajectory on mobile robot
  - Trainee's steps
  - 0:50

- Evaluation
  - Average score: 71.3

- Trajectory on mobile robot
  - Design and evaluate training trajectory
  - Trainee's steps
  - 1:35

Bio-statistics & Human-mechatronics Lab. IPS, Waseda University

Feb. 2014 - 27

Closing remarks

November 2009

Bio-statistics & Human-mechatronics Lab. IPS, Waseda University

Feb. 2014 - 20
Walking training test (1) Straight-line

- 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

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

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Procedure for training

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

Image-projective Desktop Arm Trainer, IDAT

- IDAT-1
  - Reflection type
    - V365-D470xH800mm
  - Built-in type
    - W500-D160xH360mm
- IDAT-2
  - Direct type
    - W380-D380xH600mm
  - Support mechanism
    - 7.5kg (main body)
- IDAT-3
  - Built-in type
    - W500-D160xH360mm
  - Scanning RF
    - 8.5kg (main body)

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

Parameter setting

- 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)
- (2012.06)(2:45)
- (2012.06)(2:45)

By hand keeping on screen
- (2012.06)(2:45)
- (2012.06)(2:45)
- (2012.06)(2:45)
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

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

Touch event detection
- Spread all fingers
- Fist
- Palm
- One Finger
- Five fingertips
- One fingertips

Hand/mallet distinction + Touch speed detection
- Virtual Piano
- Virtual Xylophone

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Demonstration
- Piano/Xylophone [2013.01 (1:12)]

Submitted to ACM/IEEE HRI 2014 video session, but rejected...!!!
Human detection

Result 1: rotating, walking, interrupted

Result 2: embrace

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

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

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Result

- Robot detects and locks target human
  - 1. it follows human stable
  - 2. it avoids obstacle

- Mobile phone control (2013.09) (0:21)
- Remote operation
  - Mobile phone control (2013.09) (0:21)

Robotics / Humanics

- Various robots are announced in a big event and reported widely
- However, what will robots provide after losing such extraordinary?
- 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 humanism while robotics research and development
- Robotics is Humanics (from engineering viewpoint)
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Feb. 2014