Inheriting Humanoid Systems from Remote-Brained Robotics

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1 Prof., 1 Associate Prof.
3 Assistant Profs., 35 students, 2013FY
How? Towards Whole-Body Humanoid

1983 Rope Handling 1st ISRR
1988 Dexterous Manipulation

2013 Dancing Steps
2013 Musculoskeletal Humanoid

Development
Methodology
Software
Hardware
Body Type
Environment
Behaviors
Task
Integration
Inheritance
Remote-Brained Robotics

Mother Environment

Real Environment

Robot Brain

Robot Body

Parallel Computer
Sensor Receiver
Motor Transmitter

Sensor
Effector
Power Source

Mother Environment

Brain
Body

Embodied Agent

Interface

Brain
Body

Physical Environment

Embodied Agent

1980

1990

Remote-Brained Robotics: about 60 robots

1993
6th ISRR

Embedded Brain

Concurrent Development

Remote Brained
Software Abstraction Platform for Different Type Bodies

Mother

Brain

Wireless Tower

Internet

Multi-robot

Hetero robot

Body

Quadruped

Apelike

Humanoid

Multi Mobile arms

Mother

1993 ISRR
Shared Mother Environment for different brain-body combinations

Remote-Brained Research Inheritance

Mother
Brain
Brain

Mother
Brain

Mother
Brain

Mother
Brain

Body
Body

Body
Body

Body

Real World Environment

Study on Robot Cooperative Tasks such as Handover 1998
Typical Task: Swinging with different brains
1) Human solved controller
2) Learning controller
From Swing to Brachiation 1997

Swing and reach

vision and grasp sensors

Knuckle walk 1993
Balancing 1995
Balance Manipulate 1997

Rollover 1994
Learning 1995
Body Sensor Image in Brain

Tactile Sensor Suit
1995
7th ISRR

Tactile Signal area

Integrated Sensor Image

Electrically Conductive Fabric and String
Brain & Mother Environment

(Inoue & Inaba Lab.
Dept. of Mechano-Informatics
University of Tokyo)

Worldwide computer network

WorkStation
Transputer Interface

SPARC x 20
CS6400

Transputer network

SPARC Server

1989 JSK, software on 48 Trasputers

1992 JSK, Single Trasputer with a MEP

Brain-Body Interface

Vision Subsystem

Monitor Tuner

D/A A/D

Vision Boards

Sensor Receiver

Signal Receiver

Signal Analyzer

Sensor Signal

Control Subsystem

Control Boards

Wireless Servo Controller

Control Signal

Brain-Body Interface

Stereo and 3D Tracking

Robot Bodies

Control Signal Receiver

Actuators

Video Signal Transmitter

Sensor Display

Battery

Interaction Navigation
Study on connection from perception to action

AI: Perfect Planning  
Model Feed-forward

R: Attention Selection  
Feedback loop

B: Motion Arbitration  
Parallel Structure

Robotics is the study of intelligent connection from perception to action  
1983 1st ISRR
- If/then simple control
- Simple Programmed Behaviors
- Parallel Sensor Monitoring Process
Parallel Processes from P to A

- Parallel Evaluation of Sensor States
- Action Arbitration
Process Network from Perception to Action

- Data-driven control, extensible with modularity
- Behavior Network (BeNet)
Process Network for Error Recovery Using State Network

Upper layer: State Net

Lower layer: Behavior Net
Learning connection between Perception to Action

Controller parameters

GA

Fitness

Evaluate

GA Operations

Virtual in Mother

Optical Flow Vector

Knee Angle
From small-size to life-size

1995  Auto-balancer by Small

1999  Auto-balancer by H5

1995  Auto-balancer by Small

1999  Auto-balancer by H5

2001  ladder by Small humanoid

2004  ladder by Life-size humanoid H7

PC becomes smaller and powerful

Workstation to PC

Software Extensible

Software RT Servo Controller
Life-size Humanoid to common Platform

H6 & H7 Humanoid

Dual CPU
PC board

Hardware Maintenance by Company

HRP2 Project 1998-2003
Stereo Vision on board PC
Correlation based Software Implementation with MMX

HARP: Humanoid Autonomous Robot Project H1-H7
HRP2 Tool manipulation 2005–

- Kettle pouring water
- Dust cloth wiping
- Broom sweeping
- Cleaner operation
- Playing instrument
- Washing machine operation
From Humanoid to Specialized Robots in Industry Collaboration Projects 2006

Common Integrated Software for Perception Manipulation

Audio Visual Care Robot

Dexterous Sensor-based Manipulation

Robust Task Sequence Execution

With Fujitsu

With Panasonic

With Toyota
High Speed High Powered Motor Driver 2010

Toward DRC 2012

Liquid cooled motor
New fabrication of body with free-shape bones 1995
Musculoskeletal Humanoid  2000-

More than 100 motors with wire tension driven robot.
Total System and Mother JSK Environment

Real Body
- Desktop Type
- Musculo
- Personal Mobility
- Mobile Manip
- Humanoid

Mother Environment
- Task model translator
  - Higher Layer
  - Interaction Control
  - Behavior Statenet
  - Localization Navigation
  - Motion Planning

Memory
- Task Modeling
- Success Conditions
- Env. Body Modeling

Realtime Reactive Layer
- Body Monitoring
- Reactive Control
- Sensor-Motor Body I/O

Body Model
- Desktop Type
- Furniture
- Musculo-skeletal
- Mobile Manip
- PM
- Programming Window
Abstracted description of humanoid robots

Joint space level commands
- (send *kaz3* :larm :shoulder-p :joint-angle -80)

Work space level commands
- (setq c (send *kaz3* :larm :end-coords :copy-worldcoords))
- (send *kaz3* :larm :inverse-kinematics c)
Simulation example on EusDyna 2008

Whole body effect  
Gripper  
Standup and walking  
Multi contacts
With OSS Community

- Open Source ROS
- Language from OMICS (Open Mind Indoor Common Sense)
- TUM collaboration

PR2 getting a sandwich

JSK, The University of Tokyo & IAS, Technische Universität München

Saito, Chen, Okada, Inaba, Kunze, Beetz, IROS 2011
Remote Virtual Challenge and Lab

OSRF Cloud Sim, Virtual DRC

Simulator on remote cloud system at US

PointCloud, Camera data taken at Tokyo

HRP2 Experiments in Cloud Room, 2013

HRP2 Experiments in U-Tokyo Room, 2006
Remote Testing Server

Continuous Integration Tool: Jenkins
ROS, OpenHRP,
RTM: Japanese RT middleware
OS: Different Versions/CPU word size

Download Source
Compile Software
Running on Simulator
Verify Test Results
Inheriting Humanoid Robots from RBR 2013

- Evolve to More Complex body
- Sensor Suit/Flesh
- 3D Flow Onboard vision
- Lighter devices
- Common Integration Platform
- Evolve with Open Community
- Musculoskeletal
- High Power Jump
- Push Recovery
- Spine
- Care
- Kitchen Assist
- Life Assist

Inherit: Mother
Inherit: Specialization
Remote Brain
High Power
Jump
Push Recovery
Spine
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Brain - Body Interface

(a) Computer → Tranceiver ← Computer

(b) Computer → Tranceiver ← Computer
   Transmitter

(c) Computer → Receiver ← Actuators
   Transmitter
   Transmitter
   Sensors
   Vision

(d) Computer → Receiver ← Actuators
   Transmitter
   Vision
   Sensors
**HTML/Web based robot UI**

- ROS message over http network enable us to create “portable” UI on the web browser

- Display all image view from PR2

**Movelt! (Planning Apps) Web Interface**

**3D Image Recognition result**
HTML/Web based 3D UI

Linux

Industry Teaching Tablet

Mac

Browser-based UI
In execution, the system traced a graph based on sensor observation, switched the controller parameters.
Whole-body version 2013