Artifact　Intelligence:

Yet Another Approach for Intelligent Robots

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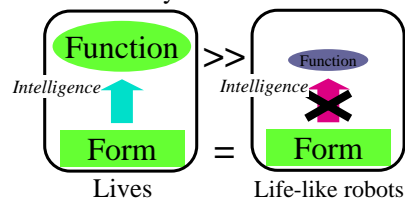*630-0101 Nara, Japan*
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Directions for intelligent robots

- Humanoid or life-like robots
  - Forms and functions are irrelevant or even interfere with each other
    - *Form follows function*
    - Functions for lives are all about survival of lives!
    - Forms should be similar to lives
    - But ..
    - The current technologies cannot realize all the functions
    - Form *cannot* follow function!
  - Functions are ill-defined
    - The ideal function for lives is "survival instinct"
    - Definitions for *practical* functions are therefore always insufficient.
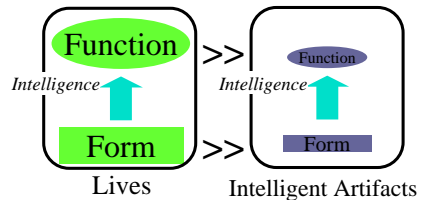

Lives   Life-like robots

Directions for intelligent robots

- *Intelligent artifacts*
  - Clear functions
    - Artifacts should have their own purpose of existence that are given by designers and users
  - Functions just for forms, Forms just for functions
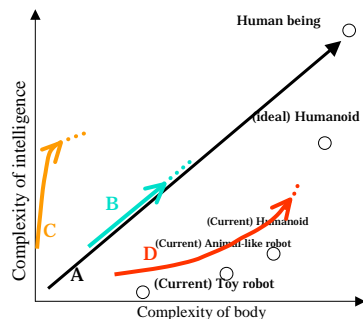   - We can use form of artifacts as base for realizing functions

Different Approaches for Intelligence

- Artificial Intelligence (+ Mechatronics)
  - Too highly intelligent!
  - Difficulty to ground Intelligence to the body
- Biology-inspired or behavior-based robots
  - Still too highly intelligent
  - Mimic to lives in functions and bodies
- Artifact Intelligence
  - Intelligence just enough to body
    - bodies not mimic to lives
    - **Coupling functions and bodies is crucial**
  - Intelligence to realize functions given as human intention
    - cf. instinct
    - **Human interaction is indispensable**
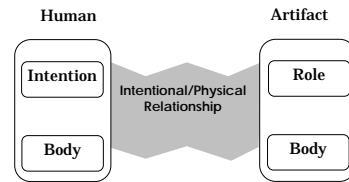
Requirements for artifact intelligence

- The basic requirements for artifact intelligence
  - Coupling functions and bodies is crucial
  - Human interaction is indispensable
- We can re-address the above issues as establishment for physical and intentional relationship between artifacts and humans
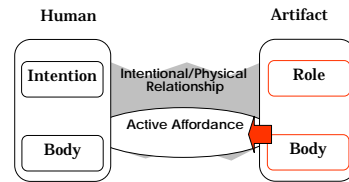
Affordance for Artifacts

- Affordance
  - *affordance refers to the possibilities for the action available in the environment or the object, and it is revealed by interaction between the human and the environment*
  - *Gibson's affordance is passive for artefacts because it is uncertain until a particular interaction initiated by humans is done*
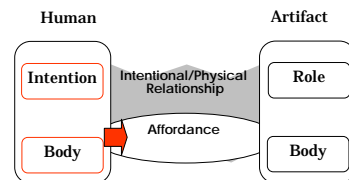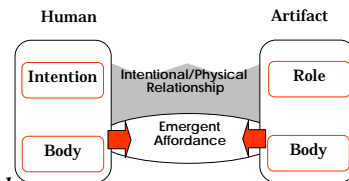
Affordance for Artifacts

- Active Affordance
  - *Extension of affordance that is realized by the artifact's action, while affordance is realized by human actions*

Human — Intention, Body
Artifact — Role, Body
Intentional/Physical Relationship
Active Affordance

- Emergent Affordance
  - *Interaction between humans and artifacts to find roles of artifacts cooperatively*
  - *Artifacts should have an ability to find their roles with new environments*

Human — Intention, Body
Artifact — Role, Body
Intentional/Physical Relationship
Emergent Affordance


How to Realize Active Affordance?

- A human action with an artifact needs specific contacts with each other

   Ex.) Drinking water   a glass and a hand   Reaching a glass.

- **Embodiment relation** = relation between surfaces of human body and artifact's body
- Active affordance
  - Artifact moving so that its body touches human **appropriately**.
    - Contact with the specific parts of both surfaces

Affordance Distance

- We focus on the contact state, i.e., terminal of action.
- Affordance distance :D
  - Maximum at the end of the task
  - Reduces as the artifact goes away form contact state.

$$D = \frac{1}{\sum d_i}$$

p_1 d_1 p_2 d_2 q_1 p_3 q_3 q_2 d_3

Chair
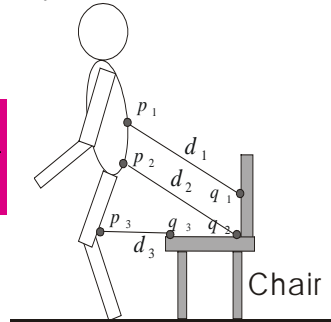
The strategy of Active artifact;
It acts in order that D will be maximized.

Reinforcement learning approach

- Learning of an optimal behavior through experience.
  - Reward is given in goal state; contact state.
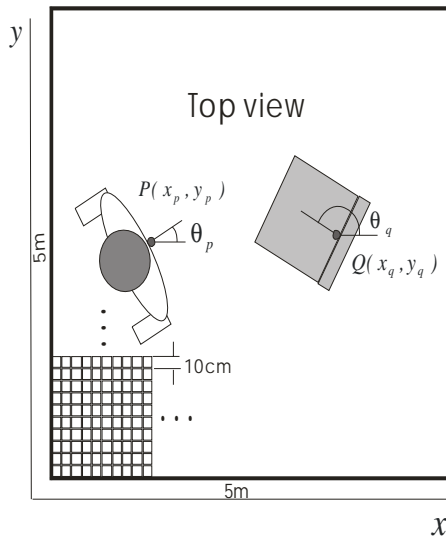- Utility function
$$U(s) \leftarrow R(s) + \max_a \sum_{s'} M_{s,s'}^a U(s')$$
  - Dynamic programming
- Optimal behavior

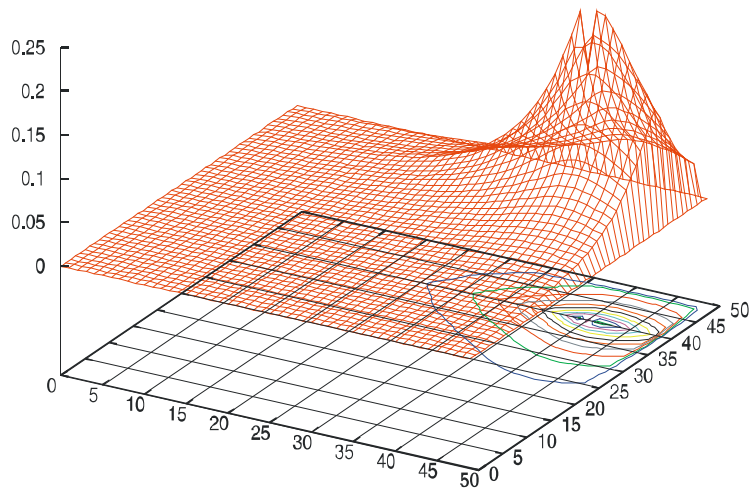$$f(s) = \arg \max_a \sum_{s'} M_{s,s'}^a U(s')$$

- Prior knowledge is not necessary.

Modeling
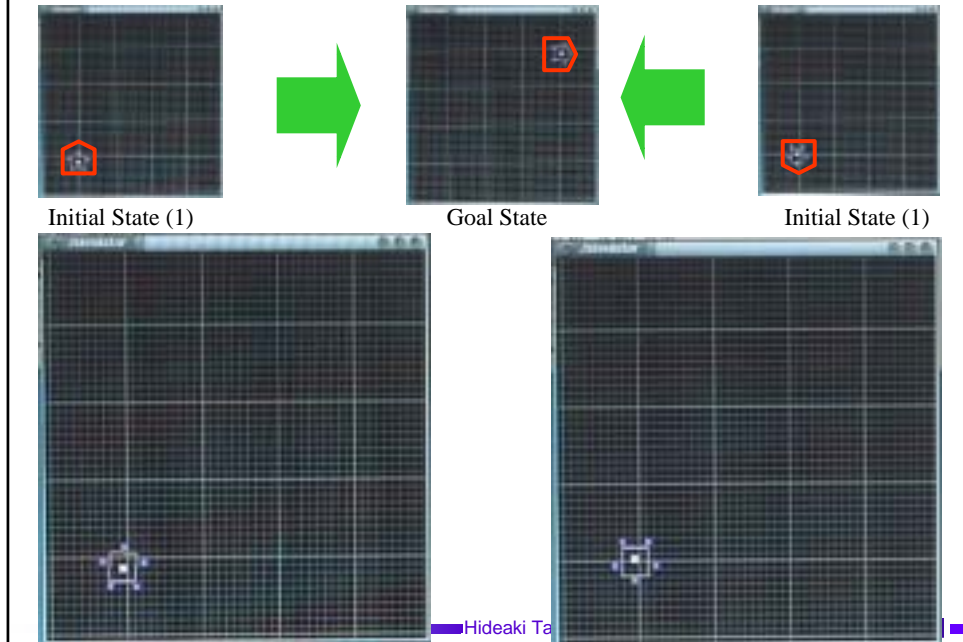
Top view

$P(x_p, y_p)$

θ_p

θ_q

$Q(x_q, y_q)$

y

5m

10cm

5m

x

- Environment
  - 5m× 5m
- State space:
  - Environment is divided into 50× 50 grid
  - (x, y,

Utility function
Goal(contact state): (40, 40, 0)

Reinforcement learning approach (1)

Initial State (1)　　　　　　　Goal State　　　　　　　Initial State (1)

Autonomous Mobile Chair

Magnetic sensor

Linux PC ←

Powered Wheel

Autonomous Mobile Chair

Emergent Affordance

- **Emergent Affordance:** Discovery of roles of artifacts via interaction with humans
  - Roles of artifacts can be specified or found with users
    - ◆ e.g., a cup can be used as a paper weight rather than a drinking device
  - Different human intention leads different roles of intelligent artifacts
- Realization of emergent affordance
  - Interaction between Human action and artifact's action
  - Human actions tell human intention to the artifacts
  - Artifacts reactions tell their interpretation of the intention under the roles and bodies
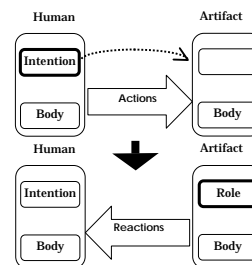
AGENT BOX

- A test case for emergent affordance
- A box with a computer, and limited sensors and actuators
- Selection of roles
  - Semi-active interaction
    - Interactive musical instrument
    - relaxation chair
  - Social interaction
    - Synchronization: Concert with multiple agents
    - Role cooperation:

AGENT BOX

- ABox
  - The first (incomplete) prototype for AgentBox
  - Structure
    - A personal computer
    - Touch panels for surfaces
      - Sensing touching, hitting and stroking
    - A speaker
  - Functions
    - Interactive musical instrument
      - Interpretation of tempo
    - (Relaxation chair
      - Interpretation of pressure)
      Not implemented yet
    - (Table)
      Not implemented yet

AGENT BOX

AGENT BOX

Summary and Future Work

- Summary
  - Artifact Intelligence:
    - A new direction for
      - Intelligence Research
      - Artifact Design
      - Ubiquitous Computing or Disappearing Computers
  - Affordance for artifact
    - A basic theory for Artifact Intelligence
      - Active Affordance
      - Emergent Affordance
- Future work
  - More consideration for affordance for artifacts
    - e.g., Consider implicit (unaware) communication
  - More active artifacts!