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.
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**

![Diagram showing the relationship between functions, forms, lives, and intelligent artifacts.](image-url)
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*

- **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*

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**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 from contact state.

\[ D = \frac{1}{\sum d_i} \]

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

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**Reinforcement learning approach**

- Learning of an optimal behavior through experience.
  - Reward is given in goal state; contact state.
- Utility function
  \[ U(s) \leftarrow R(s) + \max_a \sum_{s'} M_{s,s'} U(s') \]
  - Dynamic programming
- Optimal behavior
  \[ f(s) = \arg \max_a \sum_i M_{s,i} U(s') \]
- Prior knowledge is not necessary.
Modeling

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

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:
- 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
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:

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
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!