Towards Social System Synthesis Harmonized with Nature
- Control Perspective -

Shinji Hara  (U. Tokyo)
Our Recognition

After the Earthquake on March 11 and Fukushima

These events show that the current science and technology need careful reconsideration.

However, we must believe that that we can reach a new better world through new innovations.

Paradigm Shift

Establish Sci. and Tech. led by “Control”

Make “Control” as one of the most essential areas in sci. & tech. for the future
Realization of High Quality Products → Solving Social Problems such as Energy, Environments, and Medicine

- Classical Control
- Modern Control
- Robust Control
- Hybrid Control

- High Performance
- Automation
- Stabilization
- Multiple Functions

Applications:
- Steel process
- Chemical process
- Engine control
- Robotics
- Mechatronics
- Linear motor car
- Aerospace
- Bio-systems
- Power NWs
- Transportation
- Meteorological Phenomena
Paradigm Shift in Control

Changes in Contribution of Control

• Development and realization of products (artifacts) ➔ Design of systems and environments to solve social problems
• “Objects もの”: Development of system components ➔ “Functions コト”: “Harmonization” of total functions as systems
• Short-term values ➔ Long-term prospects: “Sustainability”

Objects to be Controlled

• In closed space (Artificial systems) ➔ In open space (Complex systems of nature, society, humans)
• Homogenous system ➔ Heterogeneous system (Varieties, Hierarchies, Multi-Resolutions)
Features of Target Systems

- **Heterogeneous interactive systems** consisting of elements and subsystems that interact with each other.
- **Systems in open environments** that function under incomplete information.
- **Systems with diverse values** that may also change depending on circumstances.

**Issues and Problems**

- Tradeoffs between optimality and robustness
- Conflicts among local/global optima
- Consensus forming in society
Harmony with Nature and Social System

Heterogeneous Networked Dynamical Systems

Physical NW

Integrated Control NW
(Measurement, Prediction & Control)

Human NW

Economic NW
OUTLINE

1. Future in Control
2. Current Control Activities in Japan for New Directions
3. Glocal Control
4. Smart Water City
5. Concluding Remarks
1. Future in Control

2. Current Control Activities in Japan for New Directions

3. Glocal Control

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5. Concluding Remarks
Current Control Activities in Japan for New Directions

- Transdisciplinary Integration initiated by SICE
- SICE City
- Smart Water City proposed by SICE
- Mobiligence: Emergence of adaptive motor function through interaction among the body, brain and environment
- Glocal Control: A New Paradigm in Control

SICE: Society of Instrument and Control Engineers
Transdisciplinary Integration
- Integration of multi-disciplinary sciences -

Promotion of new science through integration of multi-disciplinary sciences towards solving social problems

Next generation systems science

Transdisciplinary integration

Trans-view and integration

Perspective through wide field of science and technologies

Elec. Eng.  Mech. Eng.  ...  Social Science

Control Science
Modeling & Simulation
Robotics

Project oriented science and technology
Realization of new residential areas for health, safety/security, and life-long support through measurement, control and system integration

“Health”
“Safety and Security”
“Life-Long Support”

Measurement, Control, and System Integration
New Cities of Water: Utilization of various functions of water

Optimal control of water demand and supply balance

3D Water System: In harmony with nature:

Smart Creeks: Distributed water treatment & circulation system

by SICE Vision Produce Program
Glocal Control

Realization of Global Functions by Local Measurement and Control

Glocal Control System

Local Control

Global Prediction through hierarchical model with multiple-resolution

Local Measurement

LR model
MR model
HR model

Meteorological Phenomena

Bio-Systems

Power NWs

Transportation

Real World
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Glocal Control

Realization of Global Functions by Local Measurement and Control

Real World

Hierarchical Dynamical Systems with Multi-resolution

Glocal Control System

Local Control

Global Prediction

Local Measurement

Power NWs

Bio-Systems

Transportation

LR model

MR model

HR model
LTI System with Generalized Frequency Variable

A unified representation for multi-agent dynamical systems

\[ C (sI - A)^{-1} B + D \]

1/s \(\rightarrow\) \(h(s)\)

\[ \Phi(s) = 1/h(s) \]

Group Robot

Gene Reg. Networks

Dynamics + Information Structure
# Stability Tests for LTISwGFV

<table>
<thead>
<tr>
<th>Graphical</th>
<th>Algebraic</th>
<th>Numeric (LMI)</th>
</tr>
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<tbody>
<tr>
<td>Nyquist – type</td>
<td>Hurwitz – type</td>
<td>Lyapunov – type</td>
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<tr>
<td>$h(s)$ and $\sigma(A)$</td>
<td>$h(s)$ and $\sigma(A)$</td>
<td>$h(s)$ and $A$</td>
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**Hurwitz test for complex coefficients**

**Generalized Lyapunov Inequality**
Weak Inter-layer Interaction

Hierarchical Decentralized Cooperative Control

Rapid Consensus

\[ \Delta: \text{Rank 1} \]

\[ \Delta = 1 \]

Distribution

Aggregation
New Framework for System Theory

2D System

Singular Perturbed System

Multi-resolved Systems
Architecture of Glocal Control System

Desired Global Behavior

Glocal Adaptor

Inverse Hierarchical Model

Generator for Local Reference Commands

Large Scale Complex System

Local Control inputs

Hierarchical Distributed Controller

Predictor (LR)

Predictor (MR)

Predictor (HR)

Glocal Predictor

Local Measurement (HR)

Global Measurement (LR)
Smart Energy NW and Energy Saving

Smart Energy Network

Electric power network + Gas energy network

→ Multi-resolved Hierarchical Modeling
→ Multi-resolved Prediction
→ Hierarchical Decentralized Control

U Tokyo
Tokyo Gas
Fujitsu
Azbil
Hierarchical Air Conditioning System

- **Area**: Group of buildings
- **Building**: Set of floors
- **Floor**: Set of rooms

Energy saving (40%) Heat island problem

Multi-resolved Hierarchical Modeling
→ Multi-resolved Prediction
→ Hierarchical Decentralized Control

Scalability
岩手南部沖
2011年3月11日15時14分データ更新

平均水面高（m）

平均水面高偏差（m）

11日
Evacuation Guidance for Tsunami

Wave measurement system by GPS

How to set up GPS wave sensors to predict the time and height of “tsunami” properly for effective evacuation guidance?

Optimal time-, space-, level- resolutions?
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Design of New Water Space: "Smart Water City"
Diversity & Multiple Properties of Water

- Water as medium
- Capability of transportation and storing heat and energy
- Three different phases: solid, liquid, and gas

- Dischargeable Everywhere and Circulating Globally
- Unlimitedly Recyclable
Possibility of 3-di.m. Water Usage

Environment loading optimum control system

Heat of indoor air would be radiated using the water circulating inside the house (building)

Environment loading control valve

Local sanitary sewer disposing system (Membrane Bioreactor)
Smart Water City

I
New Cities of Water: Utilization of various functions of water

II
Optimal control of water demand and supply balance

III
Smart Creeks: Distributed water treatment & circulation system

3D Water System: In harmony with nature:

Circulation with underground water

by SICE Vision Produce Program
Concept of “Smart Creek”

- Creek anywhere, in your town
- Taking or sprinkling water anytime anywhere by the decentralized circulation mechanism
- Without manhole /sewage pipe
Image of “Smart Creek”

Decentralized Wastewater Treatment & Circulation System

Laundry, air-conditioning, restroom, car wash, sprinkling, ...

Smart creak unit

Water quality sensor
Flow meter
Networked Control System

Water-oriented art & message
  • Outdoor commercial, information

Hybrid control

Environmental temperature control in SC
  • Thermometer (Surface, air, ground, gray-water)
  • Linkage with weathercast

Water quality control

Urban heat sink

Sprinkling

Water rooting
  • Quality, quantity, temperature optimizer
Urban Heat Island Problem

Local Actions of Measurement & Control

Realization of Global Desired Environment of a Whole City

Scale of buildings and roads

Glocal Control

Scale of residential and business areas

Scale of districts/towns
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**Physical NW**

**Human NW**

**Economic NW**

**Integrated Control NW**
(Measurement, Prediction & Control)
Wide View of “Control”

System Harmonized With Nature and Society

Control

Adaptation

Decision Making

Predication

Learning

Recognition

Human NW

Physical NW

Real World

Economic NW

Humans

Physical

Economic

Decision Making

Optimization

System Integration

Robotics

Communication Networks

Data Mining

Signal Processing

Modeling

Learning

Predication

Recognition

Adaptation

Control
Thank you very much!