Future Direction in Systems and Control
Gifu, Japan (Sept. 9, 2012)

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

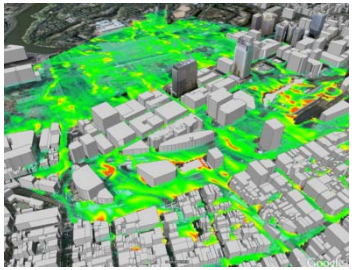
Establish Sci. and Tech. led by "Control"

Make "Control" as one of the most essential areas in sci. & tech. for the future

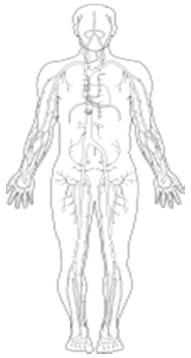
福島第一原子力発電所３号機(3/16 PM撮影)

Future Direction in Control

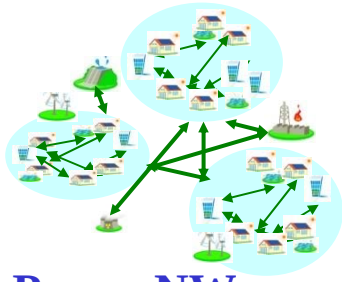
Realization of High Quality Products
→ Solving Social Problems such as
Energy, Environments, and Medicine



Meteorological Phenomena



Bio-systems



Power NWs

Transportation

Multiple Functions

High Performance

Automation

Stabilization

Hybrid Control

Robust Control

Modern Control

Classical Control

Linear motor car

Engine control

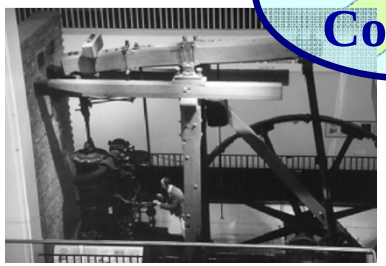
Robotics

Mechatronics

Aerospace

Steel process

Chemical process



Watt

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 モの": 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

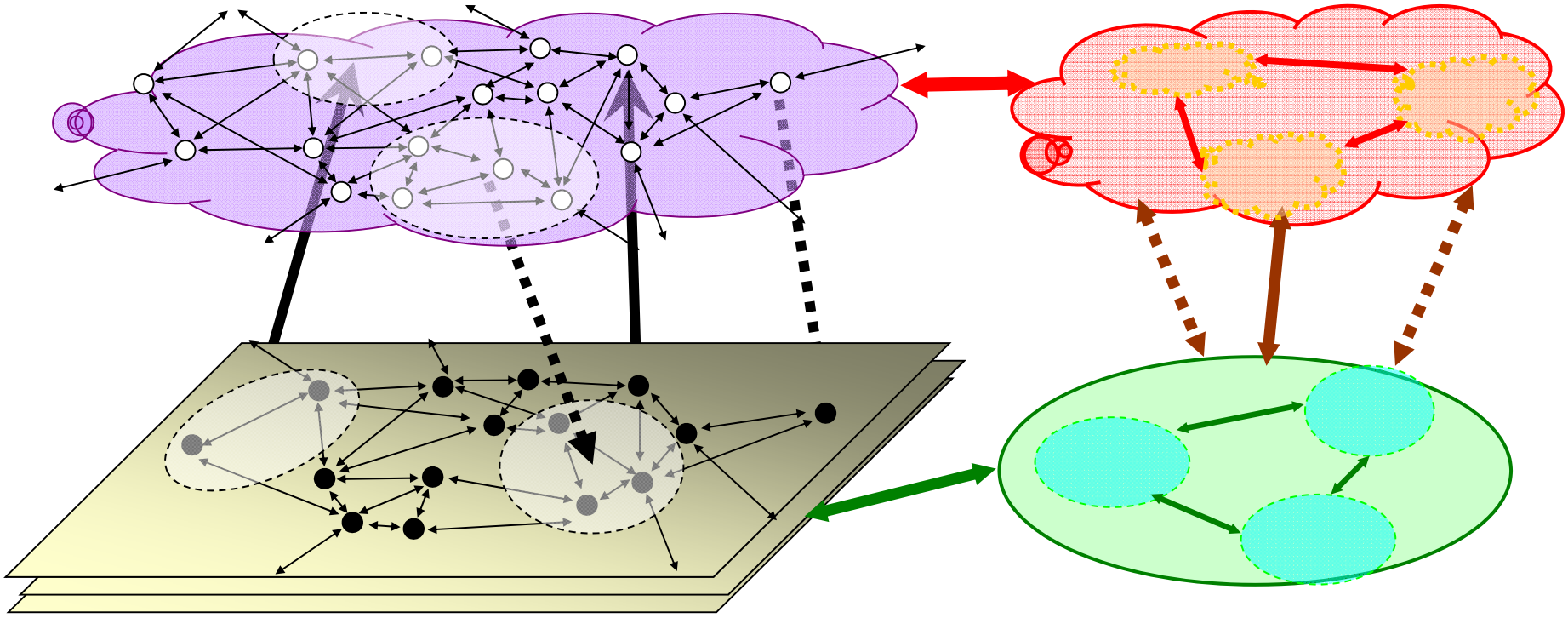
- **Heterogeneous interactive systems** consisting of elements and subsystems that interact with each other.
- **Systems in open environments** that function under incomplete information
- **Systems with diverse values** that may also change depending on circumstances

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



Integrated Control NW

(Measurement, Prediction & Control)

OUTLINE

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

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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

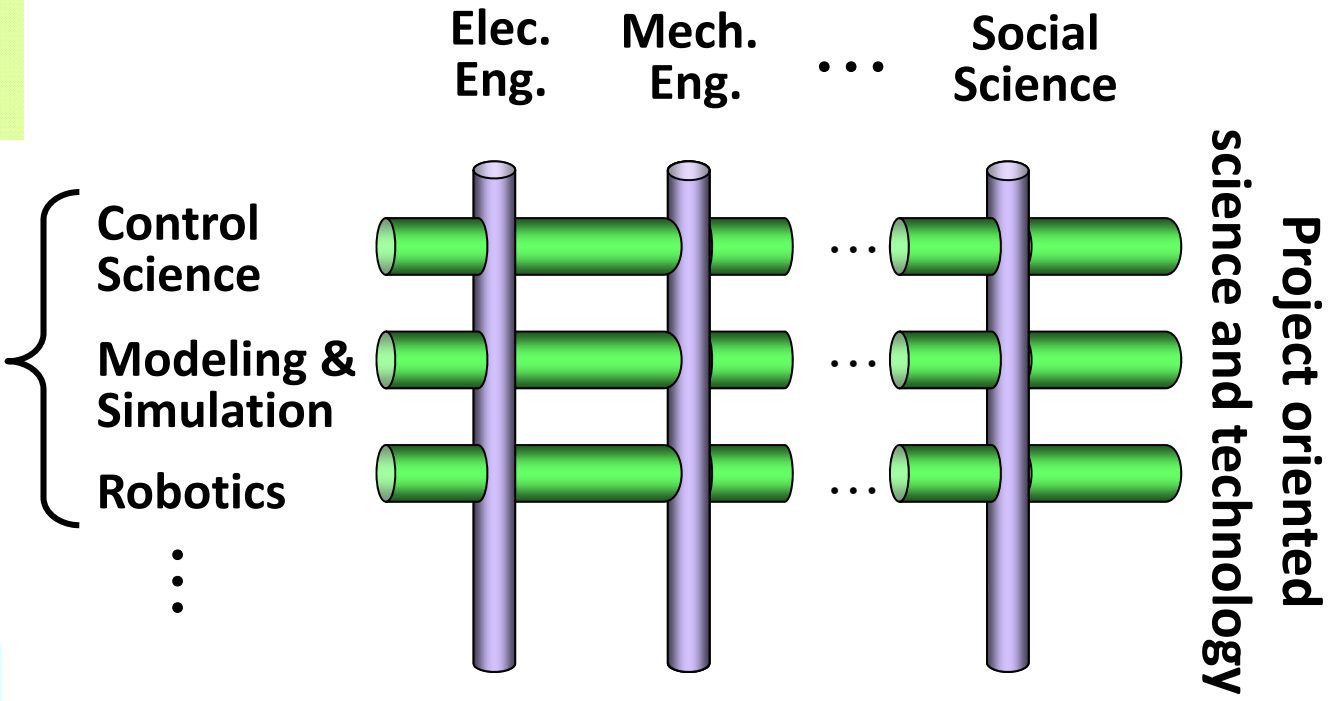
Transdisciplinary Integration
- Integration of multi-disciplinary sciences -

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

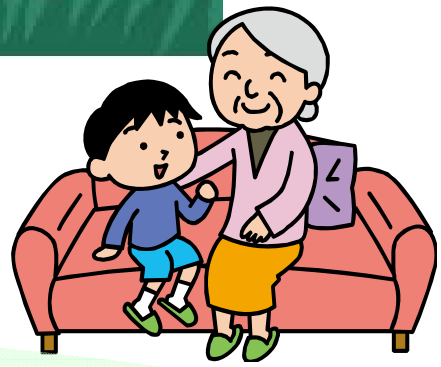
SICE City

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

“Health”

“Safety and Security”

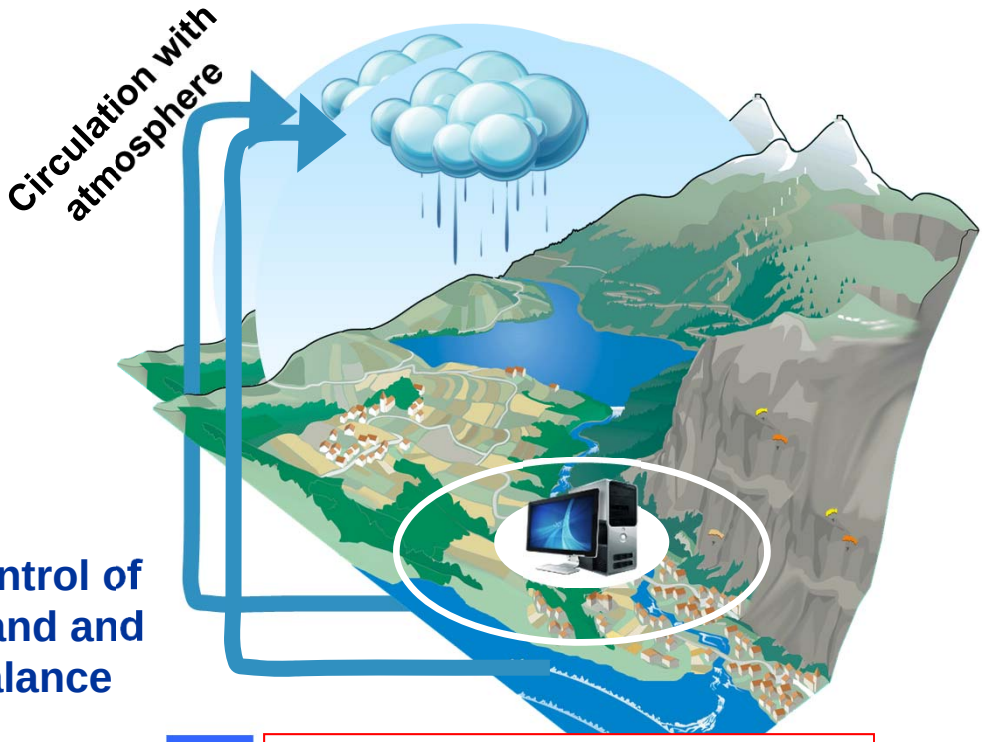
“Life-Long Support”



Measurement, Control, and System Integration

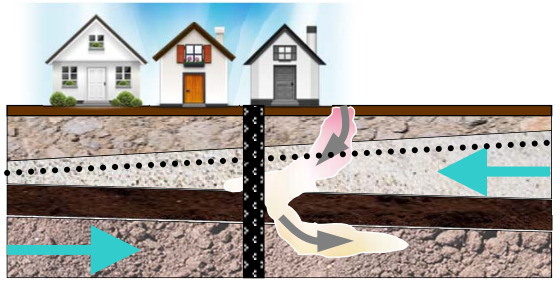
Smart Water City

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



Optimal control of water demand and supply balance

Ⅱ **3D Water System: In harmony with nature:**



Ⅲ **Smart Creeks: Distributed water treatment & circulation system**

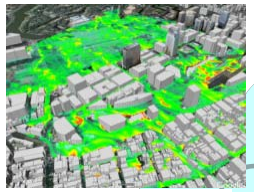
Circulation with underground water

by SICE Vision Produce Program

Glocal Control

Realization of Global Functions by Local Measurement and Control

Real World



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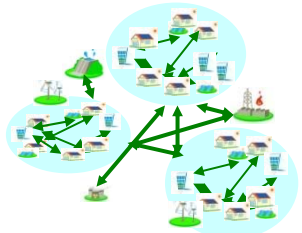
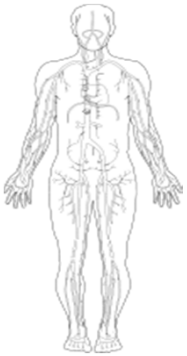


Power NWs



Bio-Systems

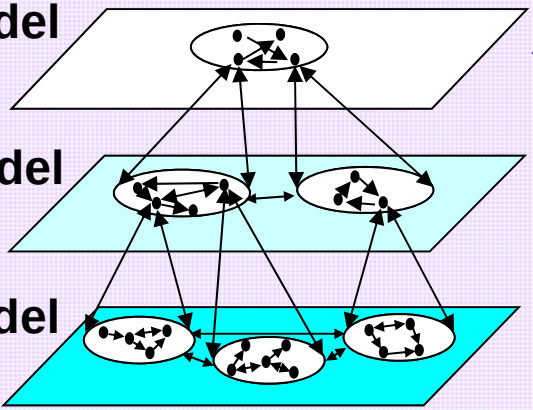
Transportation

Glocal Control System

Local Control

Global Prediction through hierarchical model with multiple-resolution

Local Measurement



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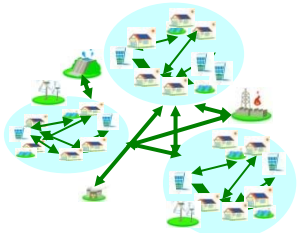
Glocal Control

Realization of Global Functions by Local Measurement and Control

Real World

Hierarchical Dynamical Systems with Multi-resolution



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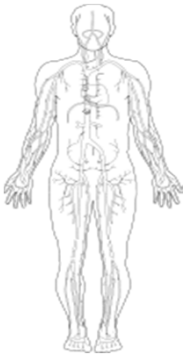

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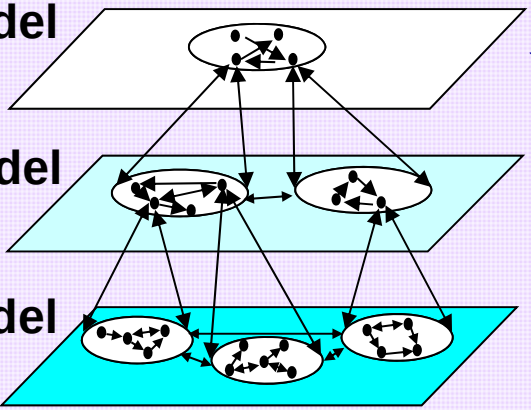
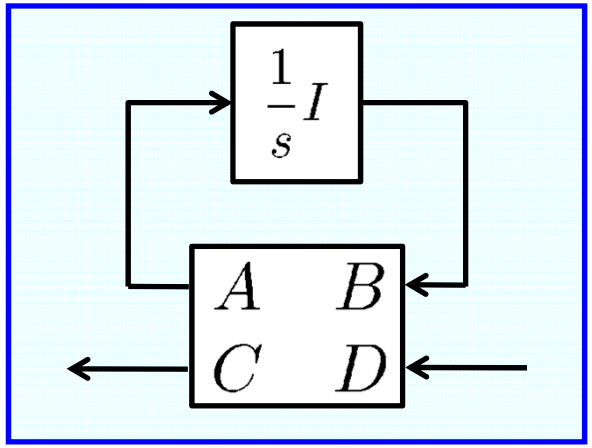


Local Measurement

LTI System with Generalized Frequency Variable

A unified representation for multi-agent dynamical systems

$C\,(sI - A)^{-1}\,B + D$

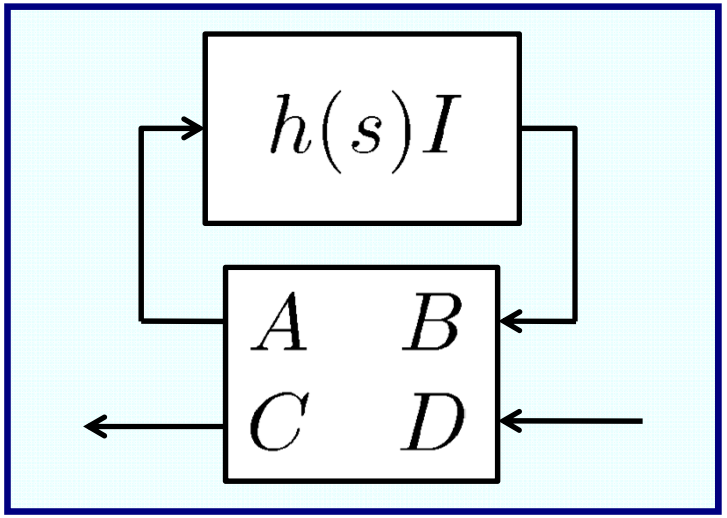


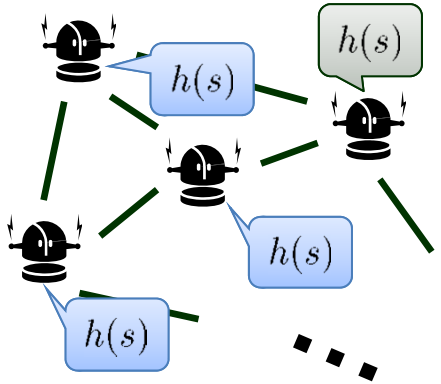
1/s → h(s)

Φ(s) = 1/h(s)

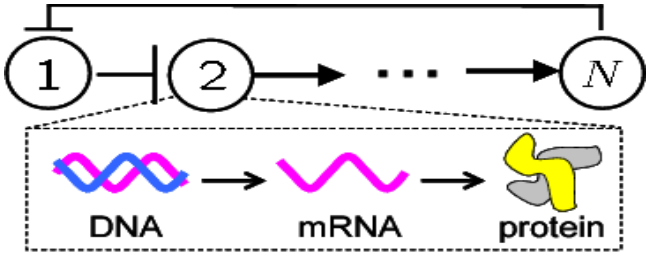
Generalized Freq. Variable

$C\,(\phi(s)I - A)^{-1}\,B + D$





Group Robot



Gene Reg. Networks

Dynamics + Information Structure

Stability Tests for LTISwGFV

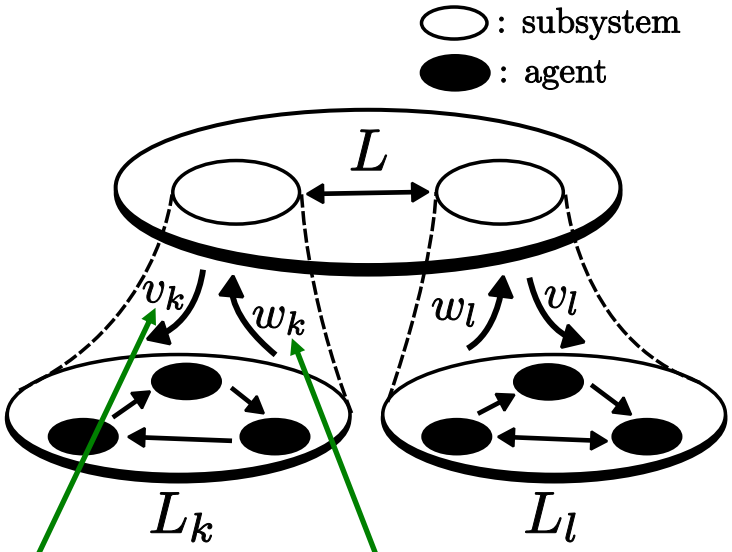
Graphical	Algebraic	Numeric (LMI)
Nyquist – type	**Hurwitz – type**	**Lyapunov – type**
Polyak & Tsypkin (1996) Fax & Murray (2004) Hara et al. (2007)	**Tanaka, Hara, Iwasaki (ASCC2009)**	**Tanaka, Hara, Iwasaki (ASCC2009)**
$h(s)$ and $\sigma(A)$	$h(s)$ and $\sigma(A)$	$h(s)$ and A

Hurwitz test for complex coefficients

Generalized Lyapunov Inequality

Weak Inter-layer Interaction

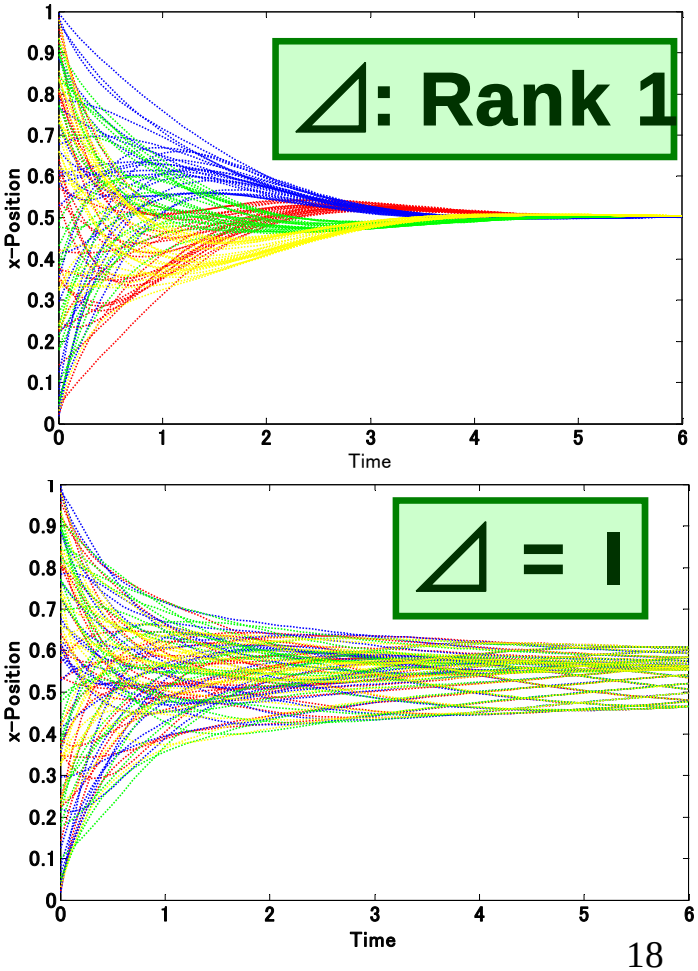
Hierarchical Decentralized Cooperative Control



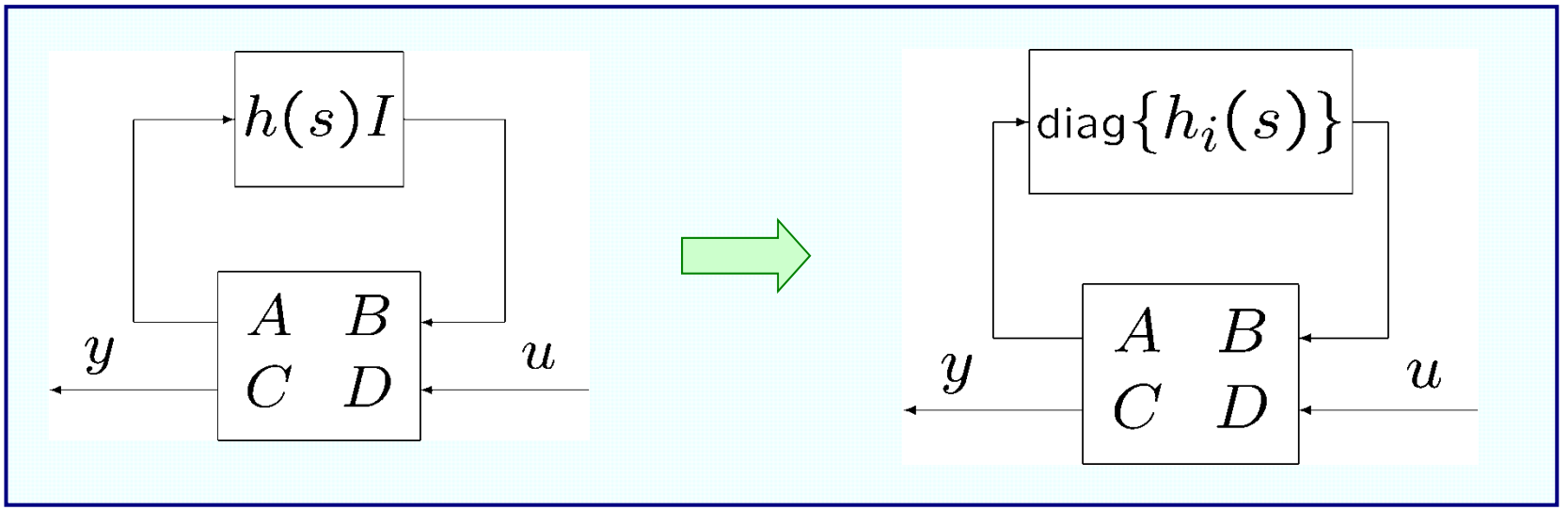
Distribution

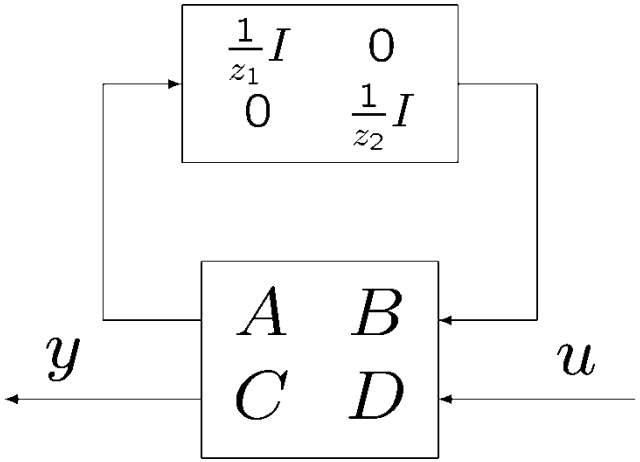
Aggregation

Rapid Consensus

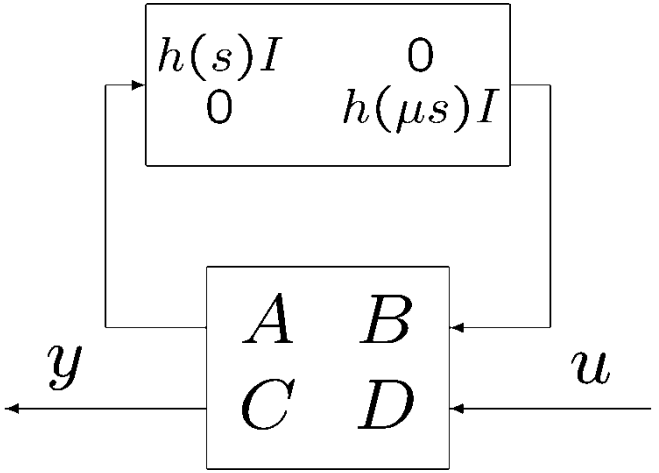


New Framework for System Theory





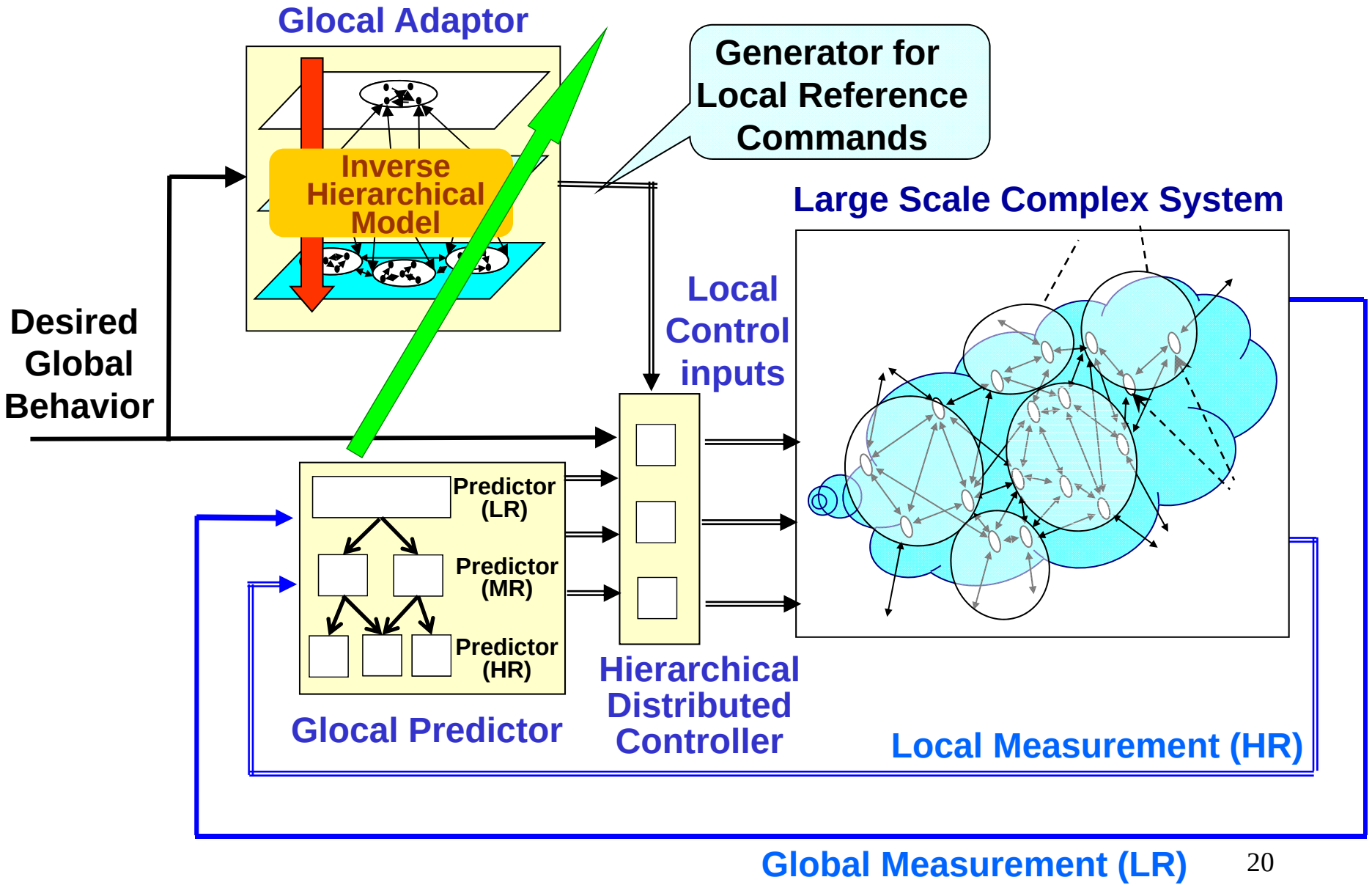
2D System



Singular Perturbed System

Multi-resolved Systems

Architecture of Glocal Control System

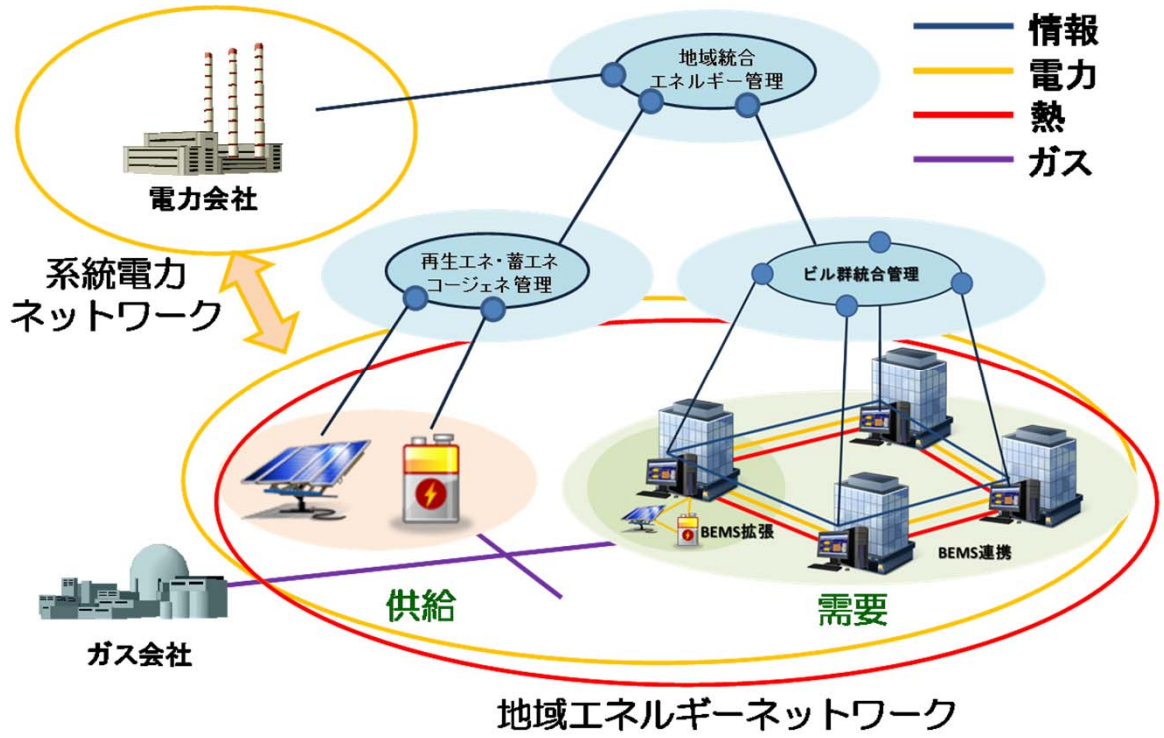


Smart Energy NW and Energy Saving

Smart Energy Network

Electric power network
+ Gas energy network

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



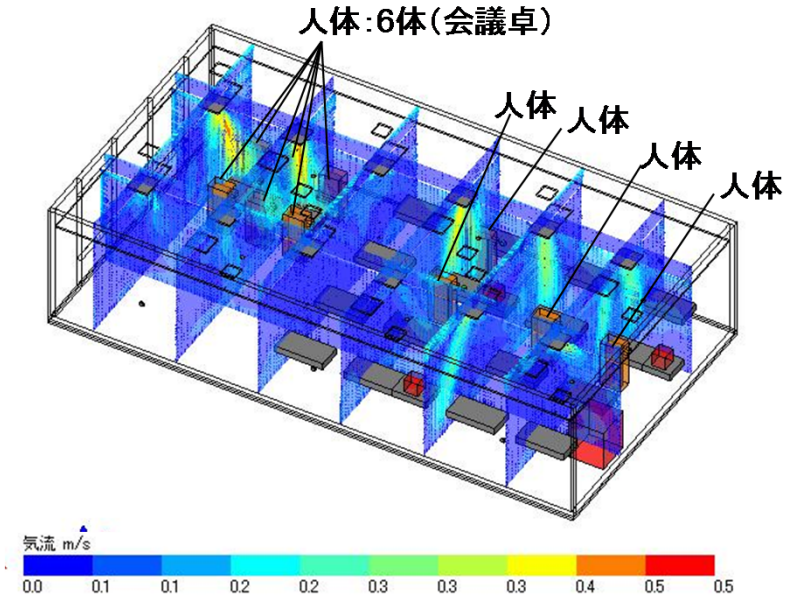
U Tokyo
Tokyo Gas
Fujitsu
Azbil

Hierarchical Air Conditioning

Hierarchical Air Conditioning System

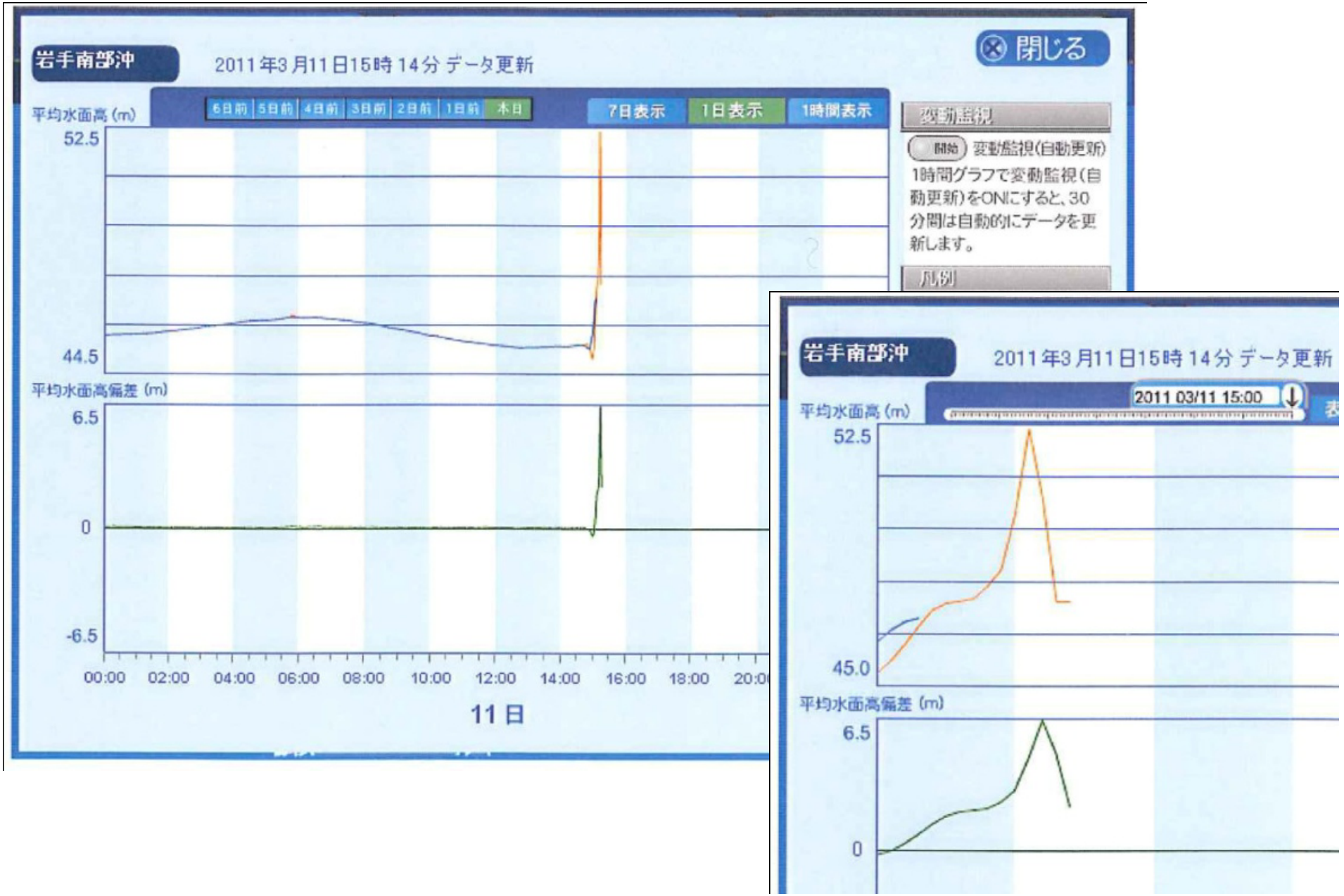
Area: Group of buildings
Building: Set of floors
Floor: Set of rooms

Energy saving (40%)
Heat island problem



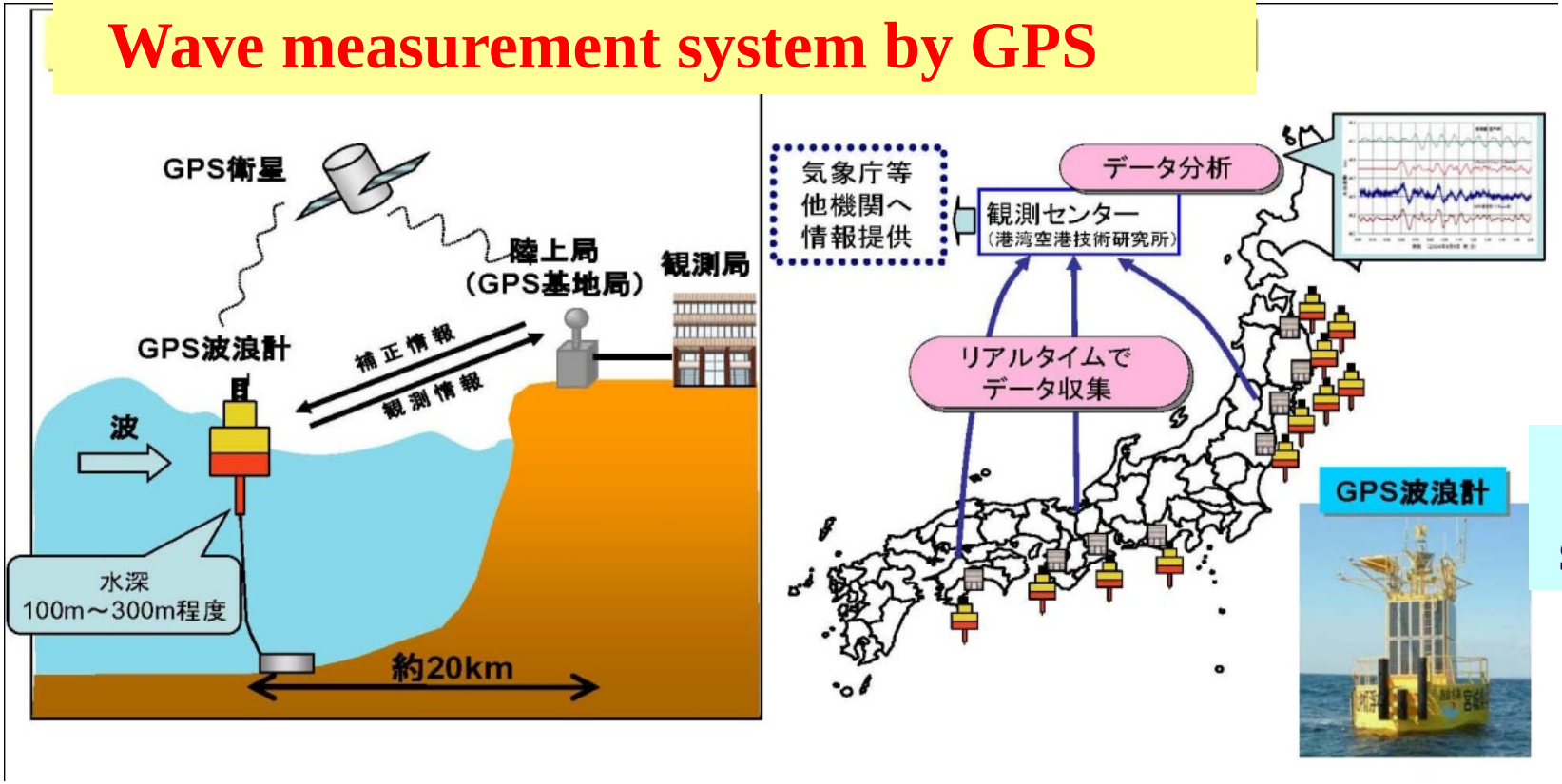
Multi-resolved Hierarchical Modeling
→ **Multi-resolved Prediction**
→ **Hierarchical Decentralized Control**

Scalability


岩手南部沖
2011年3月11日15時14分 データ更新
閉じる
6日前
5日前
4日前
3日前
2日前
1日前
本日
7日表示
1日表示
1時間表示
平均水面高 (m)
52.5
44.5
変動監視
開始
変動監視(自動更新)
1時間グラフで変動監視(自動更新)をONにすると、30分間は自動的にデータを更新します。
凡例
平均水面高偏差 (m)
6.5
0
-6.5
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
11日
岩手南部沖
2011年3月11日15時14分 データ更新
2011 03/11 15:00
平均水面高 (m)
52.5
45.0
平均水面高偏差 (m)
6.5
0

Evacuation Guidance for Tsunami

Wave measurement system by GPS



GPS Wave Sensor

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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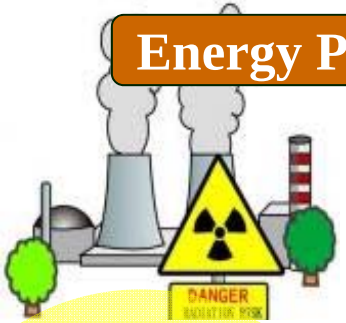
4. **Smart Water City**
5. Concluding Remarks

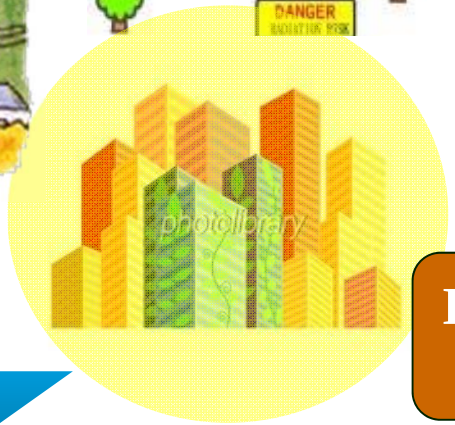
Design of New Water Space

Land Subsidence

Disasters

Energy Problem





Heat Island Problem

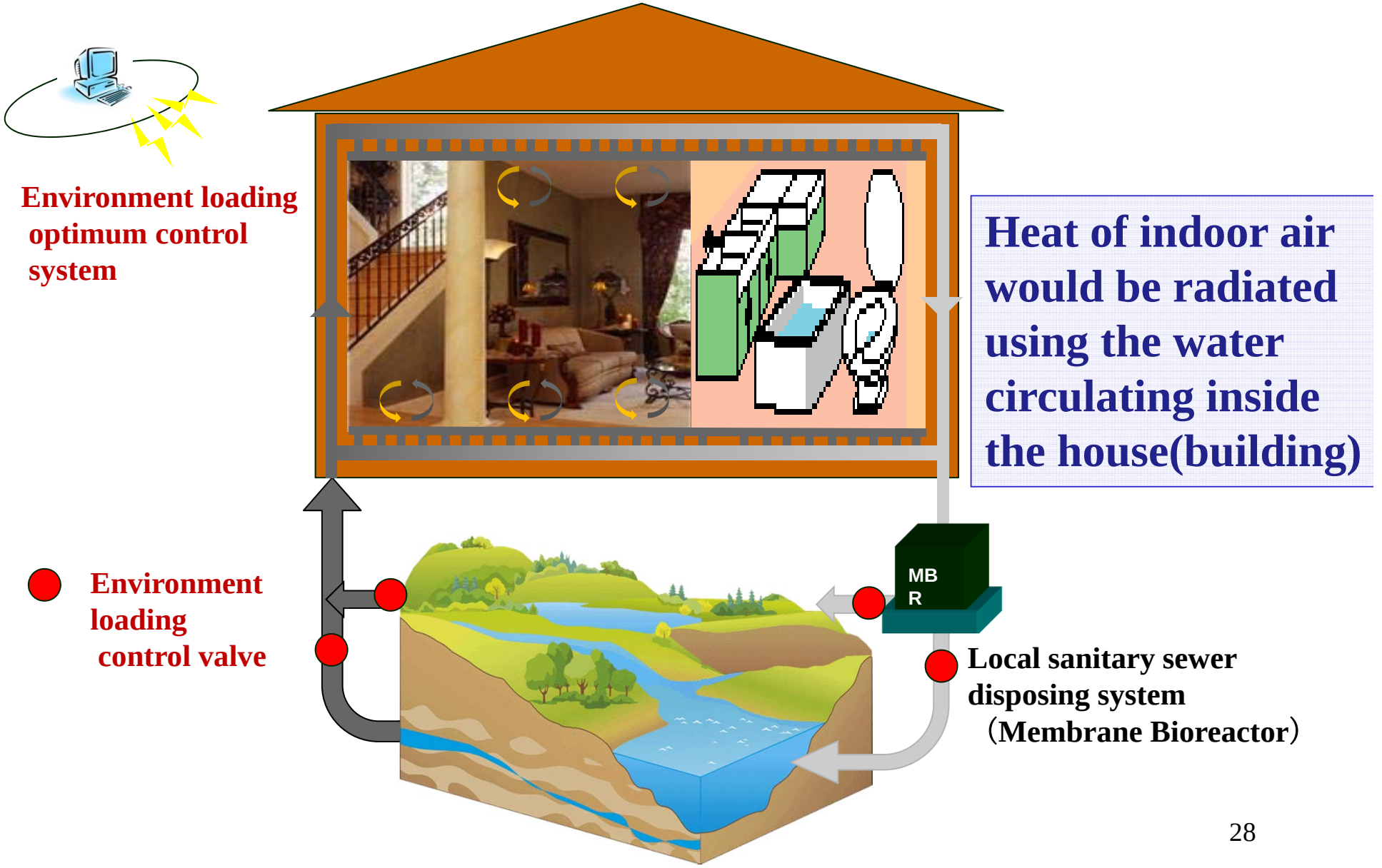
Design of New Water Space: "Smart Water City"

Diversity & Multiple Properties of Water

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

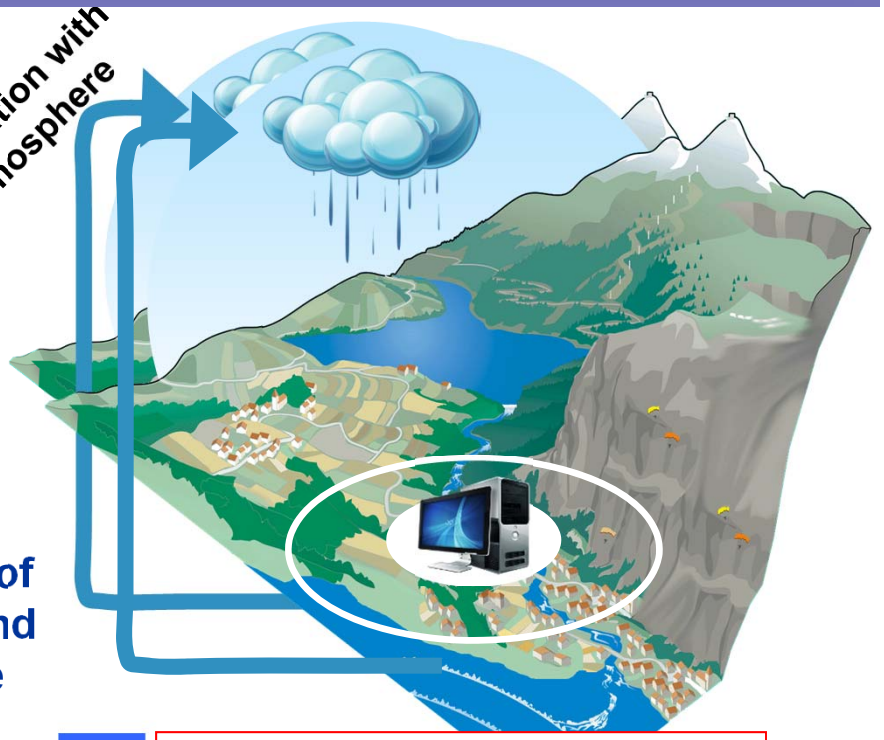
- **Dischargeable Everywhere and Circulating Globally**
- **Unlimitedly Recyclable**

Possibility of 3-di.m. Water Usage



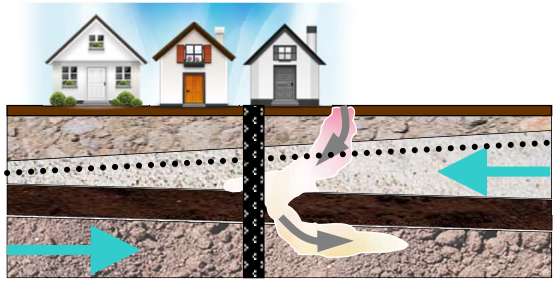
Smart Water City

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



Optimal control of water demand and supply balance

Ⅱ **3D Water System: In harmony with nature:**



Circulation with underground water

Ⅲ **Smart Creeks: Distributed water treatment & circulation system**

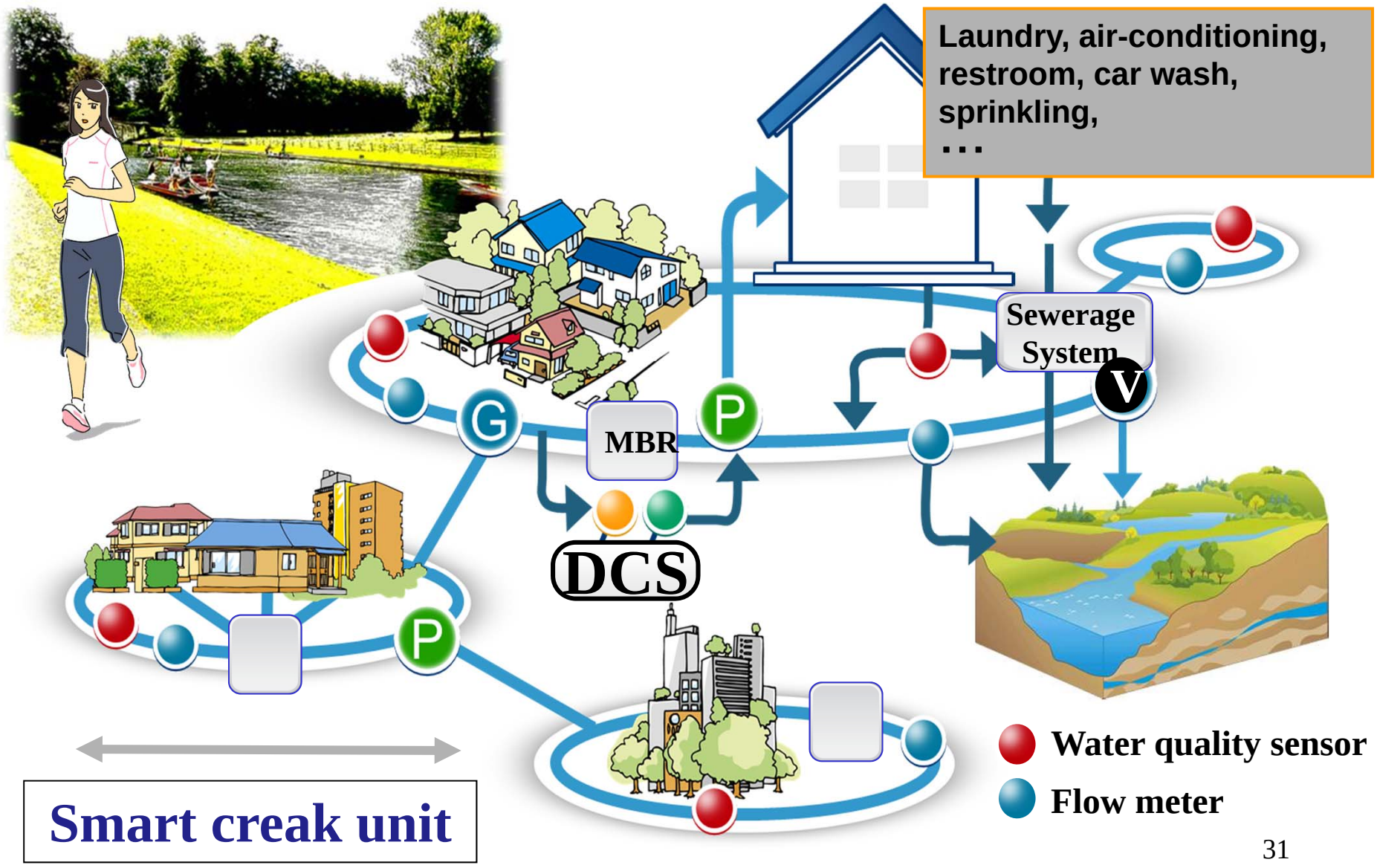
by SICE Vision Produce Program

Concept of "Smart Creek"

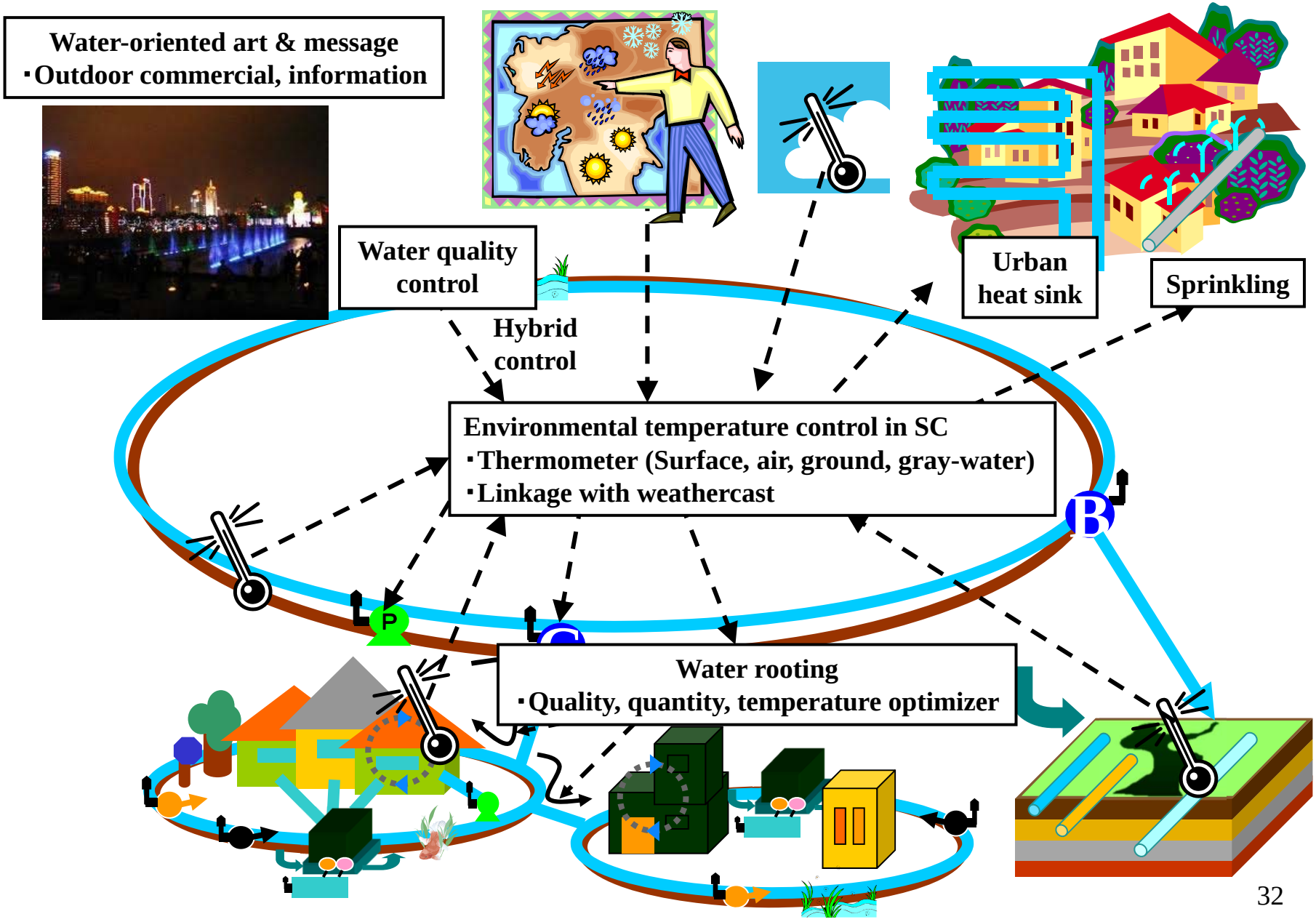
- Creek anywhere, in your town
- Taking or sprinkling water anytime anywhere by the decentralized circulation mechanism
- Without manhole /sewage pipe

Image of "Smart Creek"

Decentralized Wastewater Treatment & Circulation System

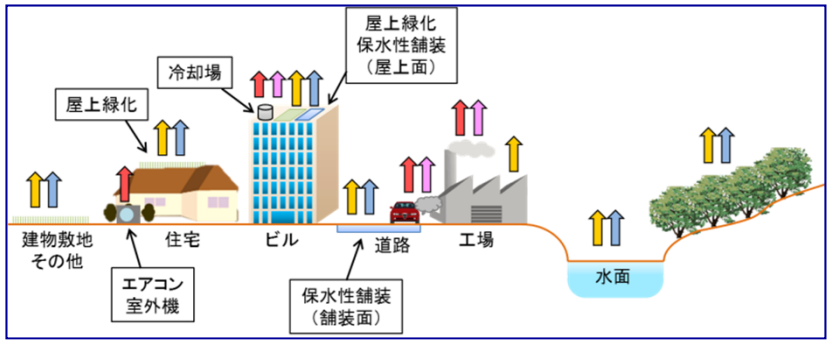


Networked Control System



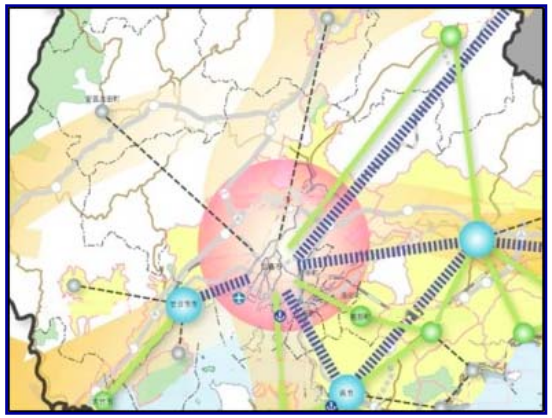
Urban Heat Island Problem

Local Actions of Measurement & Control

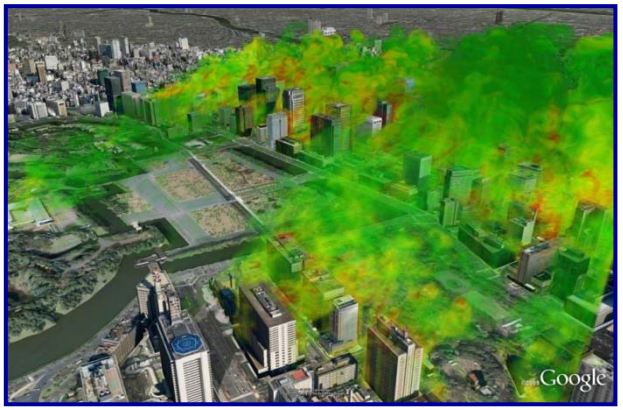


Scale of buildings and roads

Realization of Global Desired Environment of a Whole City



Glocal Control



Scale of residential and business areas

Scale of districts/towns

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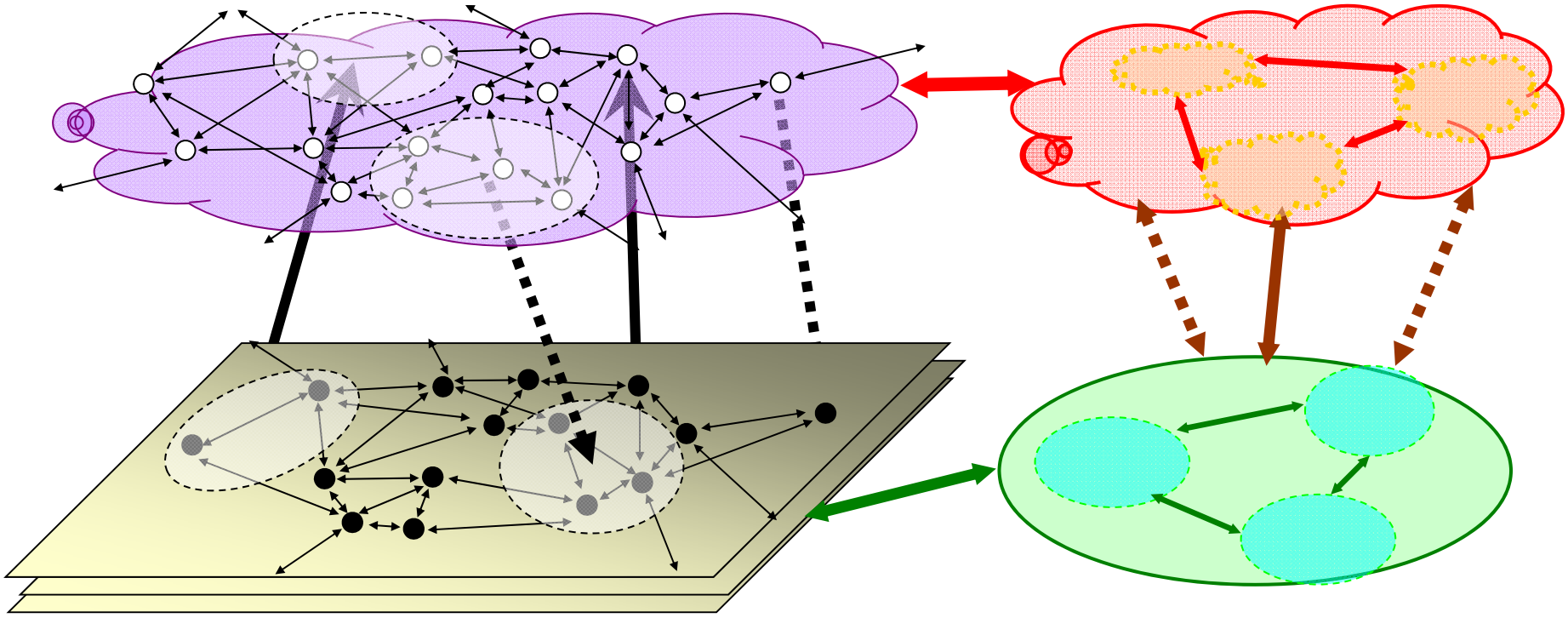
Harmony with Nature and Social System

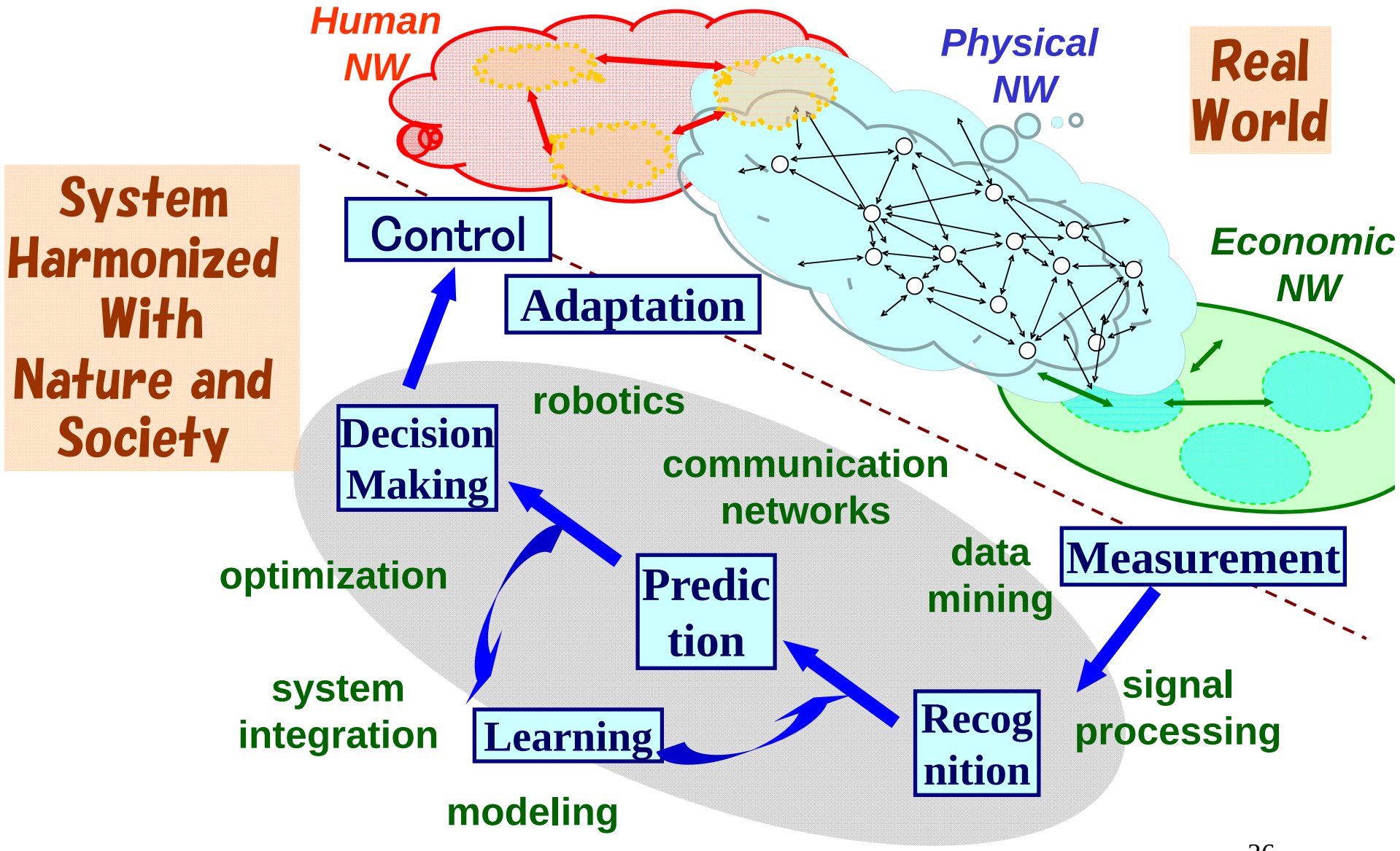
Heterogeneous Networked Dynamical Systems

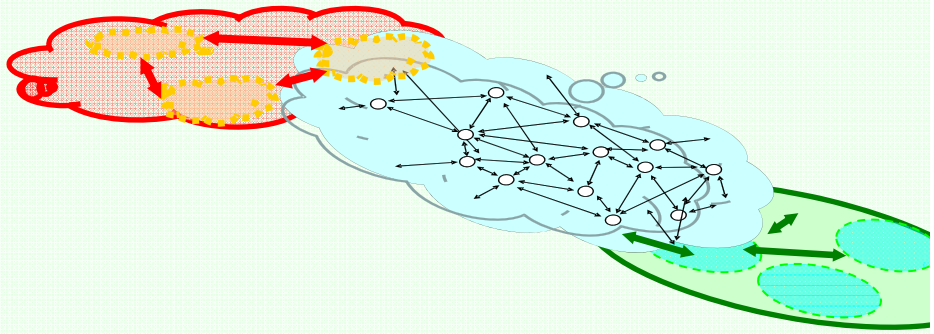


Integrated Control NW

(Measurement, Prediction & Control)

Wide View of "Control"





Thank you very much !