



The 21st Century COE Program for  
Research and Education on

# Complex Functional Mechanical Systems



## An Overview of the COE Program

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# The 21<sup>st</sup> Century Center of Excellence Program

## Initiative

- taken by the Japanese Ministry of Education, Culture, Science and Technology.

## Purpose

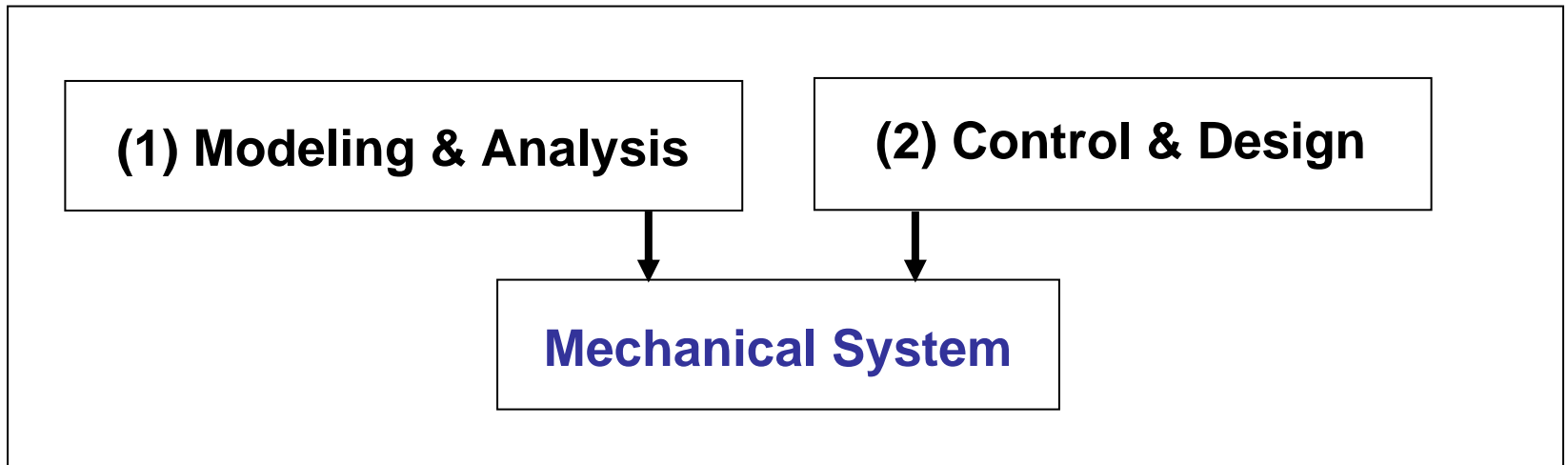
- to establish international centers for research and education in the specific research fields.

## Our COE program

- Selected in the field of Mechanical Engineering in 2003
- COE for Research and Education on “Complex Functional Mechanical systems”

# Mechanical Engineering

concern



**Mechanical system  
shift from simple to complex**

# Complex System

**comprise many elements with nonlinear interaction  
contain unstable structures**

## Important characteristics

### **(1) Order formation**

- form coherent structure through self organization

### **(2) Function emergence**

- perform higher function through coherent structure

**Basic concepts of mechanical engineering  
of complex mechanical systems**

## **(1) Atmosphere and ocean system**

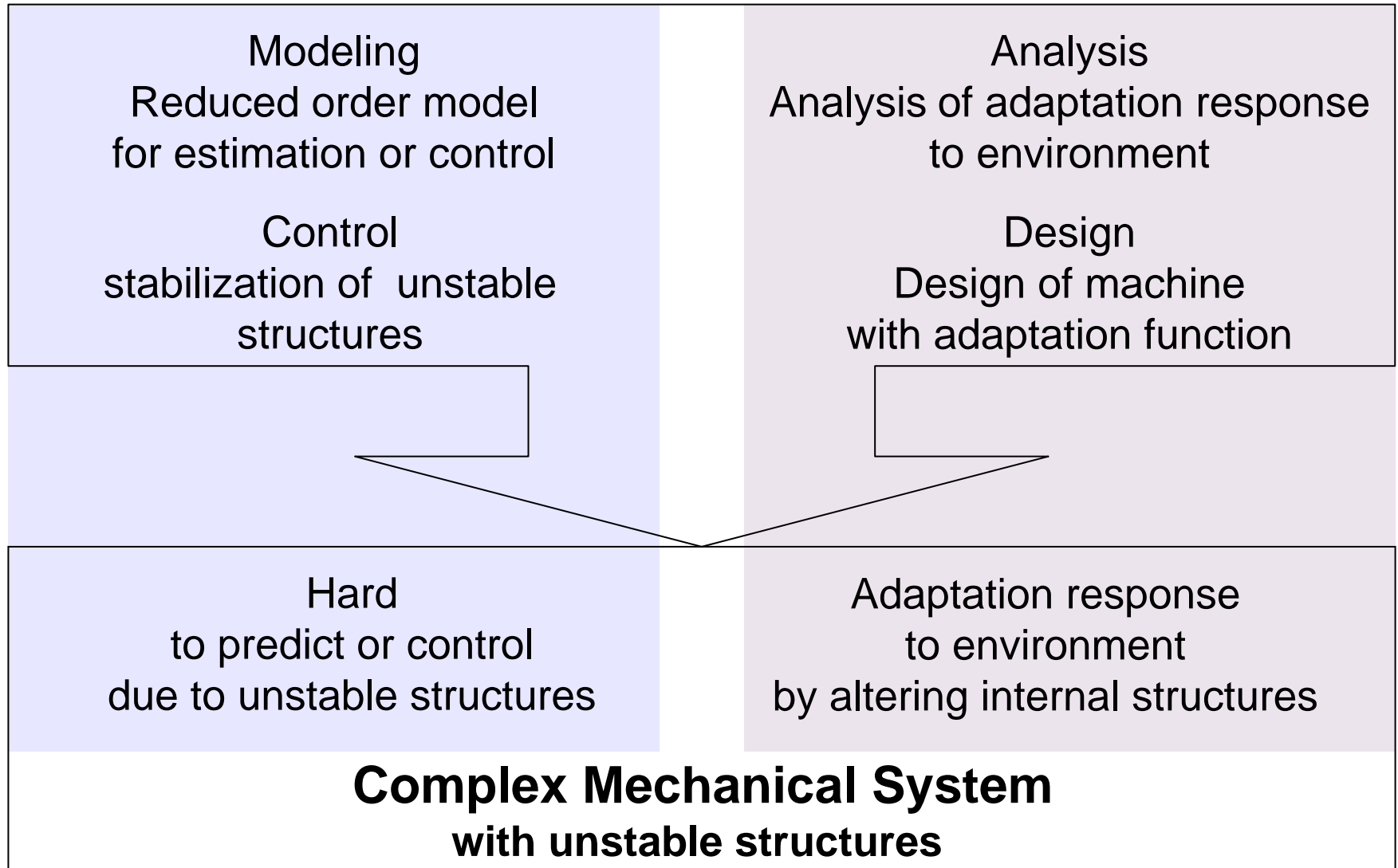
- long- term prediction of global climate change
- large scale system with many elementary processes
- compact and highly reliable model for robust prediction

## **(2) Machine system**

- function in concert with its environment
- mechanical system can change internal structures
- control of system with many degrees of freedom

**Mechanical Engineering  
for complex mechanical systems**

# Mechanical Engineering for Complex Mechanical Systems



# Research topic 1

## Modeling of complex mechanical systems

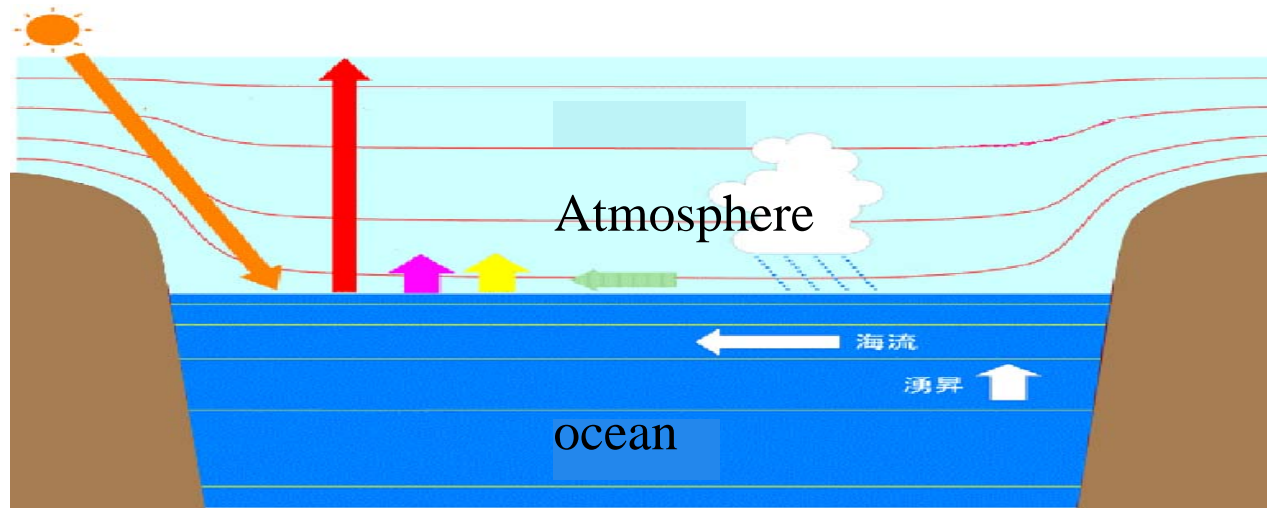
### Complex mechanical system

- hard to predict or control
- reduced order model for robust estimation or control

### Topics

- Reduced order model of atmosphere-ocean system for long-term prediction of global climate change
- Reduced order model of turbulence for control

# Modeling of atmosphere-ocean system



## Major features

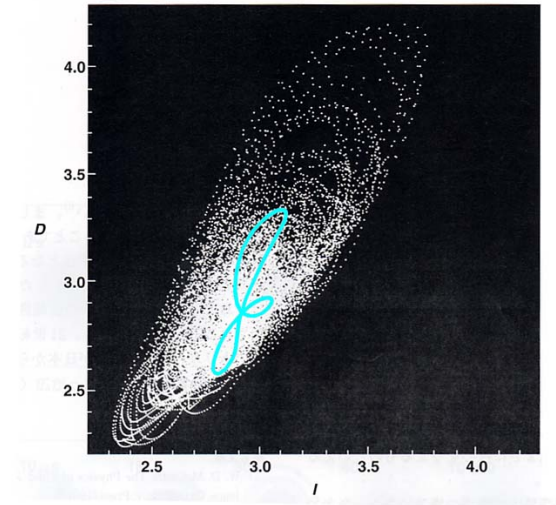
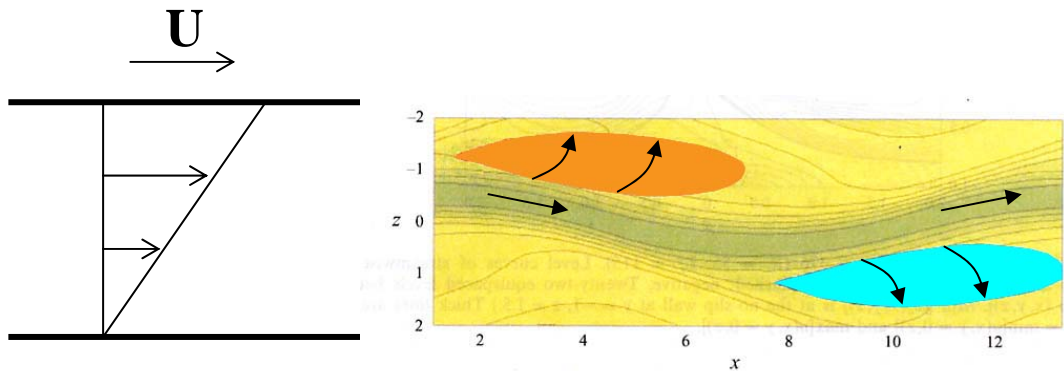
- crucial process modeled accurately by experiment
- reduced order model by conserving global structure

(Prof.Komori)



# Reduced order model of turbulence for Control

## Plane Couette turbulence



## Control algorithm

- modeling of unstable limit cycle
- stabilization of unstable limit cycle

# Research topic 2

## Analysis of Adaptation process

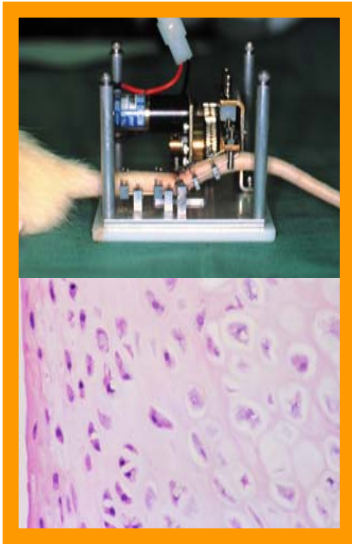
### Adaptation

- characteristic response of complex system
- exhibit adaptation by altering internal structure in response to environment

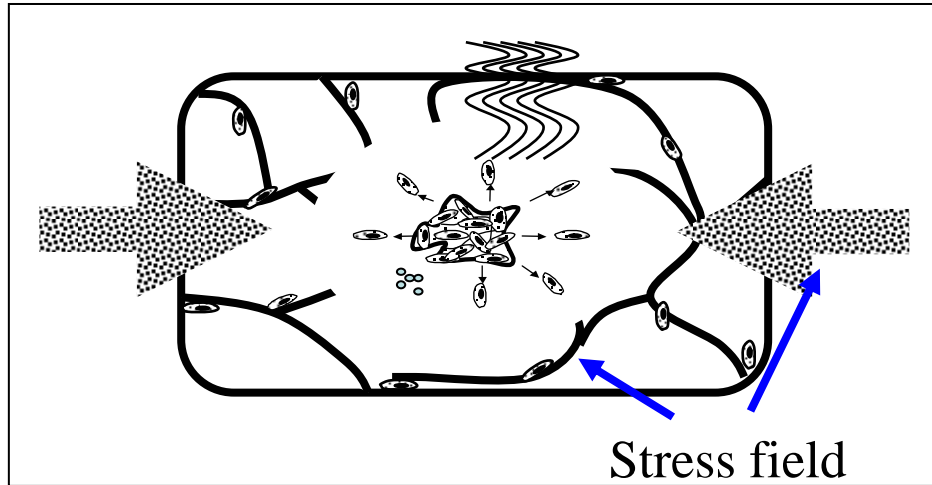
### Topics

- Analysis of adaptation process of bones under stress field for development of artificial bones

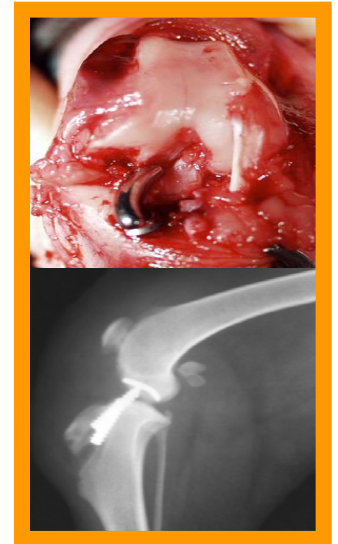
# Analysis of adaptation process undergone by bone in response to environment



- **Cartilage under cyclic stress**



- **Modeling of Adaptive response of Cartilage to cyclic stress**



- **Cartilage regeneration**

(Prof.Tomita, Prof.Adachi)

# Research topic 3

## Design of adaptive machine

### Machine

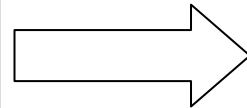
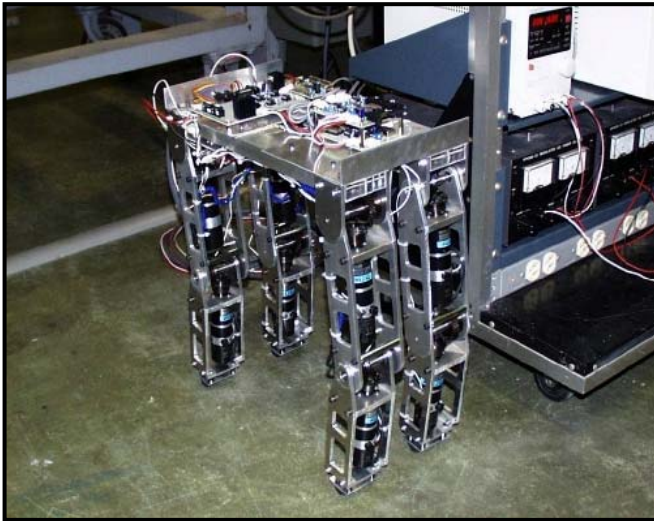
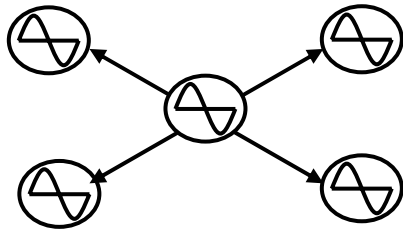
- traditionally, maximize speed and precision
- behave autonomously in a changing environment

### Adaptive machine

- Co-adaptive man-machine system
- Autonomous helicopter used at disaster site
- Locomotion robot controlled by nonlinear oscillator

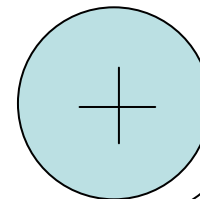
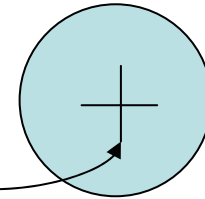
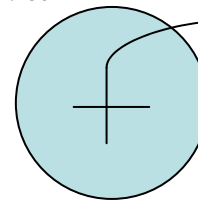
# Adaptive Machine

Nonlinear oscillator



walk

trot



Attractor