Active Dynamics

COS 426
Computer Animation

• Animation
  ◦ Make objects change over time according to scripted actions

• Simulation / dynamics
  ◦ Predict how objects change over time according to physical laws
Passive—no muscles or motors

Active—internal source of energy

Particle systems: leaves, water spray, clothing

Running human, trotting dog, swimming fish
Active Dynamics

- Motions
  - Physics
  - Controllers
  - Learning

- Behaviors
  - States

- Cognition
  - Planning
Motion

• Example 1: how do worms move?
Snake Motion
Worm Biomechanical Model

left muscle pair

right muscle pair

actuators: 20
springs’ stiffness: 50.0

point masses: 42
DOFs: 126
size of the state space: 252
Worm Physics

\[ f = k(L - I) - D \frac{dl}{dt} \]

\[ a = \frac{f}{m} \]

\[ x = \int \int (\frac{f}{m}) \, dt \]

f = force along spring direction  
k = spring force constant  
D = damping force  
I = current spring length  
L = minimum energy spring length

... plus forces due to friction with ground.
Her Majesty’s Secret Serpent
Fish Motion

• Example 2: how do fish move?
Spring-Mass Model for Fish
Hydrodynamic Locomotion

\[ m_i \frac{d^2 x_i}{dt^2} + \zeta_i \frac{dx_i}{dt} - w_i = f_i^w \]
Motor System

Behavior

Controller

Motor Skill

Degrees Of Freedom

Geometry

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Swimming
Animating Human Athletics

Hodgins
Animating Human Athletics
Learning Motions

Control system

- Brain
- Sensors

Effectors

Physical simulation

- Body
- 3D World

Sims94
Learning Muscle Controllers

\[ E(u(t)) = \int_{t_0}^{t_1} (\mu_1 E_u(u(t)) + \mu_2 E_v(v(t))) \, dt, \]
Learning to Swim
Evolved Virtual Creatures

Controllers


Mutations

a. Crossovers:

parent 1

parent 2

child

b. Grafting:

parent 1

parent 2

child

Physics & Objective

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Evolved Virtual Creatures
Multi-Level Controllers

**BASIC ABSTRACTED CONTROLLERS**
- turn down controller
- turn up controller
- move forward controller
- turn left controller
- turn right controller

**HIGHER ORDER CONTROLLER USED FOR JUMPING OUT OF WATER**
- move forward controller
- turn up controller
- turn down controller
- turn right controller

Grzeszczuk95
Learning Complex Motions
Active Dynamics

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Behavior

Sensors → Behavior → Motor System → User

- Motivational
- Task
- Direct

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Fish Behavior Controller
Intention Generator

- **Collision Detection**: Drager of collision? [Yes/No]
  - If Yes: $I^{t-1} = avoid$

- **Predator Detection**: $F > f_0$? [Yes/No]
  - If Yes: $I^t = escape$
  - If No: $F < f_i$?
    - If Yes and likes schooling?: $I^t = school$
    - If No and empty?:
      - If Yes: $I^t = school$
      - If No: $I^t = escape$
    - If No: pop the memory [Yes/No]
      - If Yes: $I^s = eat$ or $mate$?
        - If Yes: go to the focuser
        - If No: $I^t = eat$
      - If No: go to the next layer

- If $I^{t-1} ≠ avoid$: push the memory

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*Tu94*
Underwater World of JC

The Undersea World of Jack Cousto
Multi-Level Control

Motivational Level
just do the right thing
"you are hungry"

Task Level
do THIS the right way
"go to that tree"

Direct Level
do what I tell you
"wag your tail"

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Active Dynamics

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Pyramid Diagram:
- Cognitive
- Modeling
- Behavioral
- Physical
- Kinematic
- Geometric

Funge99
Planning

Goal Generation
- User Commands
- Scripting Engine
- Behavior Module

High-Level Goals

Motion Synthesis

Graphic Display

Virtual Sensor Information
- Physically-Based Simulations
- Library of “Canned Motions”
- Planning Algorithms
Motion Planning
Summary

- Motions
  - Physics
  - Controllers

- Behaviors
  - Learning

- Cognition
  - Planning