Active Dynamics

COS 426
Computer Animation

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

Simulation
  ◦ Predict how objects change over time according to physical laws

Pixar

University of Illinois
Simulation

- Kinematics
  - Considers only motion
  - Determined by positions, velocities, accelerations

  Dynamics
  - Considers underlying forces
  - Compute motion from initial conditions and physics
Passive—no muscles or motors

User \rightarrow Initial conditions \rightarrow Model

Model \rightarrow State

Graphics

Particle systems
Leaves
Water spray
Clothing

Active—internal source of energy

User \rightarrow Desired behavior \rightarrow Control

Control \rightarrow Forces and torques \rightarrow Model

Model \rightarrow State

Graphics

Running human
Trotting dog
Swimming fish

Hodgins
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

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

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

\[ X = \frac{1}{m} \int \int f dt dt \]

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.

Miller88
Her Majesty’s Secret Serpent
Fish Motion

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

Tu94
Hydrodynamic Locomotion

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

Behavior

Controller

Motor Skill

Degrees Of Freedom

Geometry
Animating Human Athletics

Hodgins
Animating Human Athletics

Hodgins
Learning Motions

Control system

Brain

Sensors

Effectors

Physical simulation

Body

3D World
Learning Muscle Controllers

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

- **Controllers**
  - Genotype: directed graph
  - Phenotype: hierarchy of 3D parts

- **Mutations**
  - a. Crossovers:
    - parent 1
    - parent 2
    - child
  - b. Grafting:
    - parent 1
    - parent 2
    - child

- **Physics & Objective**

*Sims94*
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
Learning Complex Motions
Active Dynamics

- Motions
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Diagram:
- Geometric
- Kinematic
- Physical
- Behavioral
- Cognitive
- Modeling
Behavior

Diagram:
- Sensors
- Behavior
- Motor System
- User
  - Motivational
  - Task
  - Direct

Reference: Blumberg95
Fish Behavior Controller

3D Virtual World

Artificial Fish

Sensors

Perception

Intention Generator

Habits

intention

Behavior Routines

control parameters

Motor Controllers

Actuators (Muscles)

Underlying Physical Model

Motor (Action)
Intention Generator

If $I^{t-1} \neq \text{avoid}$, push the memory.

1. Collision detection: danger of collision?
   - Yes: $I^1 = \text{avoid}$
   - No:
     - Pop the memory:
       - No, empty?:
         - Yes: Generate new intention $I^t$ by checking the mental state and the habit string
           - $I^1 = \text{escape}$
           - $I^1 = \text{school}$
       - No: go to the focuser
goto the next layer

2. Predator detection: $F > f_0$?
   - Yes:
     - $F < f_1$ and likes schooling?
       - No:
         - Yes, hungry?:
           - No:
             - Yes: $I^1 = \text{eat}$
             - No: $I^t = \text{school}$
           - Yes: $I^t = \text{wander}$
         - Yes: $I^t = \text{school}$
       - No: go to the focuser
Underwater World of JC
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"
Active Dynamics

- Motions
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Summary

- Motions
  - Physics
  - Controllers
- Behaviors
  - Learning
- Cognition
  - Planning