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

- Initial conditions
- Model
- Numerical integrator
- Particle systems
  - Leaves
  - Water spray
  - Clothing
- Graphics

Active—internal source of energy

- Desired behavior
- Control
- Forces and torques
- Model
- Numerical integrator
- Running human
  - Trotting dog
- Swimming fish
- Graphics

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

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

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

\[ x = \int \int (f/m) \, dt \]

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

Miller89
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

Motor System

Controller

Motor Skill

Degrees Of Freedom

Geometry

Behavior
Fish Motion

• Example 2: how do fish move?
Animating Human Athletics

Hodgins
Animating Human Athletics

Hodgins
Learning Motions

Control system

Brain

Sensors

Effectors

Physical simulation

Body

3D World

Sims94
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


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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Behavior

Sensors → Behavior → Motor System → User

Motivational
Task
Direct
Fish Behavior Controller

3D Virtual World

Artificial Fish

Sensors

Perception

FOCUSER

Habits

Intention Generator

intention

Behavior Routines

control parameters

Motor Controllers

Actuations (Muscles)

Underlying Physical Model

Motor (Action)
Intention Generator

collision detection
danger of collision?
Yes
No

I^t = avoid

 Predator detection

F > f_o ?

Yes
No

I^t = avoid

Predator detection

F < f_i ?

and likes schooling?

No
Yes

I^t = escape
I^t = school

if I^{t-1} \neq avoid
push the memory

pop the memory

empty?

No
Yes

I^s = eat or mate?

No
Yes

I^t = wander
I^t = school

Generate new intention I^t
by checking the mental state
and the habit string

go to the focusser

go to the next layer

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"
Active Dynamics

- Motions
  - Physics
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- Behaviors
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- Cognition
  - Planning
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

Kuffner
Motion Planning
Summary

- Motions
  - Physics
  - Controllers

- Behaviors
  - Learning

- Cognition
  - Planning