Active Dynamics

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Passive vs. Active Dynamics

**Passive—no muscles or motors**
- User
- Initial conditions
- State
- Graphics
- Model:
  - Numerical integrator
  - Particle systems
  - Leaves
  - Water spray
  - Clothing

**Active—internal source of energy**
- User
- Desired behavior
- Forces and torques
- State
- Graphics
- Model:
  - Numerical integrator
  - Running human
  - Trotting dog
  - Swimming fish

*Hodgins*
Active Dynamics

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

How Do Worms/Snakes Move?

Funge99

Grzeszczuk95
Worm Biomechanical Model

Grzeszczuk95

Worm Physics

... plus forces due to friction with ground.  Miller88
Eric the Dynamic Worm

The Fall

Snake Motion

Grzeszczuk95
Her Majesty’s Secret Serpent

Spring-Mass Model for Fish
Hydrodynamic Locomotion

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

Swimming

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“On the Run”

Animating Human Athletics

Hodgins

Raibert
Animating Human Athletics

All motion in this animation was generated using dynamic simulation.

Alien Occurrence

Alien Occurrence
Learning Motions

Sims94

Learning Muscle Controllers

Grzeszczuk95

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

Evolved Virtual Creatures

Controllers

Physics & Objective

Mutations
Evolved Virtual Creatures

Examples from work in progress

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

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Learning Complex Motions

Behavior

[Diagram: Behavior flowchart with levels: Behavior, Controller, Motor Skill, Degrees Of Freedom, Geometry]
Behavior

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Fish Behavior

Tu94
Fish Behavior Controller

Intention Generator
Go Fish!

Tu94

Underwater World of JC

Tu94
### Multi-Level Control

<table>
<thead>
<tr>
<th>Motivational Level</th>
<th>Task Level</th>
<th>Direct Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>just do the right thing</td>
<td>do THIS the right way</td>
<td>do what I tell you</td>
</tr>
<tr>
<td>&quot;you are hungry&quot;</td>
<td>&quot;go to that tree&quot;</td>
<td>&quot;wag your tail&quot;</td>
</tr>
</tbody>
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*Blumberg95*

### Silas T. Dog

*Blumberg*
Silas T. Dog

External World

- World
- Sensory System
- Releasing Mechanism

Goals/Motivations

- Internal Variable
- Internal Variable
- Level of Interest
- Inhibition
- Motor Commands

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Duffy the Merman

Funge99
Summary

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