In this talk

- Brief review of autonomous characters
  - Definitions
  - Applications

- Steering behaviors
  - Toolkits and procedural composition
  - Evolutionary computation
  - Physical realism
    - Point–mass versus rigid–body dynamics
Autonomous characters

• Self-directing characters, operate autonomously
  - "Puppets that pull their own strings" (Ann Marion)

• Combination of:
  - Geometrical model of body
  - Animation data or procedures for body
  - Behavioral model
Autonomous characters in animation

© 1994 and 1998
Walt Disney Pictures
Autonomous characters in games
Autonomous characters: groups

• Individual
  – simple local behavior
  – interaction with:
    • nearby individuals
    • local environment

• Group:
  – complex global behavior
Types of behavioral models

- **Kinematic** (animation)
- **Dynamic** (physical simulation)
- **Volition**
  - **Reactive**
    - Like instinct, off-the-cuff decision making
  - **Rule based**
    - Expert system: search through large knowledge base
  - **Planning**
    - Search through space of actions and consequences
A behavioral hierarchy

• Action selection
  – Setting goals, picking strategies

• Path selection: steering
  – Character’s motion through its world

• Pose selection: locomotion
  – Legs walking, arms reaching
  – Wheels rolling
  – etc.
Steering behaviors

- Simple, basic behaviors
  (seek, flee, wander, ...)
- Operators to combine them
  (sum, prioritized selection, dithered decision trees)
- Toolkit of simple and combined behaviors
Simple physical model

- Point mass model:
  - Position, adjusted by velocity
  - Velocity, adjusted by steering forces
  - Linear momentum, but mass has zero radius, so no moment of inertia
- Body shape: sphere (or ellipsoid)
- Velocity—aligned local coordinate system
  - Animated geometrical model can be attached
Point mass vehicle model (1)
Point mass vehicle model (2)
Steering details: *seek* and *flee*
Steering behavior demos
Boids and flocking

- *Historical note: fits in better here, but actually preceded general steering behaviors (1987)*
- Natural flocks are beautiful, and a bit mysterious
  - Can they be portrayed in computer animation?
  - Perhaps gain some insight into how they work?
    - *(ALife --- artificial life)*
  - Can the complex group behavior be explained in terms of simple behavior by the individuals?
    - *(CAS --- complex adaptive systems)*
Boids: three rules

- Three rules seemed *necessary*:
  - Separation
    - Don’t get too close to nearby flockmates
  - Alignment
    - Try to move at the same speed and direction (velocity) as nearby flockmates
  - Cohesion
    - Prefer to be at the center of the local flockmates
- Early experiments verified they were *sufficient*. 
Boids: three rules

Separation  Alignment  Cohesion
Boids for animation production

- Obstacle avoidance
- Flocking
  - Separation
  - Alignment
  - Cohesion
- Attraction to (or repulsion from) a moving target
Stanley and Stella in Breaking the Ice
Pigeons in the Park

- Based on the 1987 boids model of flocks, herds and schools
- Uses fast hardware (PS2), and spatial data structures to accelerate boids: about 6000 times faster than in 1987.
- Allows real time (60 fps) interaction with a group of about 300 birds.
- Includes behavioral state transitions
Pigeons in the Park video
Coevolution of Tag Players

- The game of tag
  - symmetrical pursuit and evasion
  - role reversal
- Goal: discover steering behavior for tag
- Method: emergence of behavior
  - coevolution
  - competitive fitness
- Self–organization:
  - no expert knowledge required
Sensors and obstacles
It works!

![Graph showing comparison between population best and average versus handmade program.](image-url)
Typical fitness test (1)
Typical fitness test (2)
Competitive coevolution: summary

**Pros:**
- Good results, comparable to human–designed players
- Diversity and skill gradation from evolution history
- Does not require knowing a winning strategy or how to implement it.

**Cons:**
- Requires very long computation time even for a very simple game.
- Untested for games requiring complex strategy.
Steering and physical realism
Steering and physical realism

• Previous topics use simplistic models of physics

• Work in progress:
  – Real time rigid body dynamics simulator (Eric Larsen)
  – Virtual robot soccer world (Eric Larsen)
  – Autonomous steering behaviors for playing soccer

• More accurate physical model requires more sophisticated steering behaviors.
Earlier work: simplified physics

- Boids (1987), steering behavior toolkit (GDC 1999)
  - Point mass model:
    - Position
    - Velocity, so linear momentum
    - Zero radius, so no moment of inertia
  - Spherical (or ellipsoidal) body

- Evolution of steering behaviors
  - *Physically plausible* kinematic model
Steering for accurate physical models

- Moment of inertia (angular momentum)
  - Must model and compensate for rotational velocity
    - Over-steering and heading oscillation

- More accurate collision modeling
  - Catching corners
    - Non-spherical body shapes
    - Friction
  - Collision avoidance more critical
  - Back up to unwedge
Simple pursuit behavior

- Faster target
- Slower target
Oversteer due to angular momentum
Pursuit with heading prediction
Conclusions

• Autonomous characters
  – Definitions
  – Applications

• Steering behaviors
  – Toolkits and procedural composition
  – Evolutionary computation
  – Issues related to accurate physical models