

Autonomous Characters in Games Steering Behaviors

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Autonomous Characters for Games and Animation

- *Self-directing* characters which operate autonomously
(“puppets that pull their own strings” -Ann Marion)
- Applications in:
 - games and other interactive venues
 - animation for television and feature films
- History:
 - first used experimentally in 1987
 - in wide commercial use today

Autonomous Characters

- Autonomous agents for simulated 3D worlds
 - situated
 - embodied
- Intersection of several fields
 - ethology
 - artificial life
 - autonomous robotics
 - dramatic characters
- Adjunct to physically-based modeling
 - dynamics versus volition
 - bouncing ball versus pursuing puppy

Reactive Behavior

- Behavior driven by reaction to environment
 - both passive scenery and active characters
- Simplifies complex animation
 - many characters can be animated by a single behavior
- Allows user interaction
 - improvisational style permits unscripted action

Applications of Autonomous Characters

- Behavioral animation (film and television)
 - coordinated group motion
 - extras / background action
- Interactive multimedia (games / virtual reality)
 - opponents and allies
 - background characters
- Autonomous robotics
 - search / exploration / mapping
 - prototyping for evolutionary robotics
- Theoretical biology
 - testing theories of emergent natural behavior

Creating Character Behaviors

- By design
 - programming
 - authoring
(example: Motion Factory)
- Through self-organization
 - evolution
 - and other forms of *machine learning*:
 - neural nets
 - decision trees
 - classifier systems
 - simulated annealing

Ad hoc Behavioral Hierarchy

- Action selection
 - goals and strategies
- Path selection / steering
 - global motion
- Pose selection / locomotion
 - local motion (animation)

Combining Simultaneous Behaviors

- Combination
 - discrete selection
 - behavioral blending
- Low priority behavior should not be:
 - completely locked out
 - allowed to contradict (and perhaps cancel out) a higher priority behavior

Behavioral Blending

- Summation / averaging
- Prioritized sequential selection
 - first active
 - stochastic (dithered) decision tree

Behavioral Animation

Behavioral Animation

- Background action
- Autonomous characters
 - behavioral model
 - graphical model
- Improvised action

Behavioral Animation: Group Motion

- Individual
 - simple local behavior
 - interaction with:
 - nearby individuals
 - local environment
- Group:
 - complex global behavior

Behavioral Animation: Examples of Group Motion

GAMEDevelopers

- People
 - crowds, mobs, passersby
- Animal
 - flocks, schools, herds
- Vehicle
 - traffic

Applications of Behavioral Animations

GAMEDevelopers

- 1987: *Stanley and Stella in: Breaking the Ice*, (short)
Director: Larry Malone, Producer: Symbolics, Inc.
- 1988: *Behave*, (short)
Produced and directed by Rebecca Allen
- 1989: *The Little Death*, (short)
Director: Matt Elson, Producer: Symbolics, Inc.
- 1992: *Batman Returns*, (feature)
Director: Tim Burton, Producer: Warner Brothers
- 1993: *Cliffhanger*, (feature)
Director: Renny Harlin, Producer: Carolco.
- 1994: *The Lion King*, (feature)
Director: Allers / Minkoff, Producer: Disney.

Applications of Behavioral Animations

GAMEDevelopers

- 1996: *From Dusk Till Dawn*, (feature)
Director: Robert Rodriguez, Producer: Miramax
- 1996: *The Hunchback of Notre Dame*, (feature)
Director: Trousdale / Wise, Producer: Disney.
- 1997: *Hercules*, (feature)
Director: Clements / Musker, Producer: Disney.
- 1997: *Spawn*, (feature)
Director: Dippé, Producer: Disney.
- 1997: *Starship Troopers*, (feature)
Director: Verhoeven, Producer: Tristar Pictures.
- 1998: *Mulan*, (feature)
Director: Bancroft/Cook, Producer: Disney.

Applications of Behavioral Animations

GAMEDevelopers

- 1998: *Antz*, (feature)
Director: Darnell/Guterman/Johnson, Producer: DreamWorks/PDI.
- 1998: *A Bugs Life*, (feature)
Director: Lasseter/Stanton, Producer: Disney/Pixar.
- 1998: *The Prince of Egypt*, (feature)
Director: Chapman/Hickner/Wells, Producer: DreamWorks.
- 1999: *Star Wars: Episode I--The Phantom Menace*, (feature)
Director: Lucas, Producer: Lucasfilm.
- 2000: *Lord of the Rings: the Fellowship of the Ring* (feature)
Director: Jackson, Producer: New Line Cinema.

Autonomous Character Case Studies

GAMEDevelopers

- Hand programmed
 - steering behavior library
 - boids
 - hockey players
- Evolution
 - corridor following
 - tag players

Steering Behaviors

GAMEDevelopers

- seek or flee from a location
- pursuit and evasion
- arrival (position / velocity / time constraints)
- obstacle avoidance / containment
- path / wall / flow field following
- group behaviors
 - unaligned collision avoidance
 - Leader following
 - flocking (three components)

GAMEDevelopers

Steering Behaviors

...steering behavior demos...

GAMEDevelopers

Boids

GAMEDevelopers

Boid Flocking

(three component steering behaviors)

- Separation
 - steer to move away from nearby flockmates
- Alignment
 - steer toward average heading of nearby flockmates (accelerate to match average velocity of nearby flockmates)
- Cohesion
 - steer towards average position of nearby flockmates

GAMEDevelopers

Boids: Separation

GAMEDevelopers

Boids: Alignment

GAMEDevelopers

Boids: Aggregation

Boids

GAMEDevelopers

(full behavioral model)

- Obstacle avoidance
- Flocking
 - separation
 - alignment
 - cohesion
- Migratory (attraction / repulsion)

Boids Web Page

GAMEDevelopers

<http://www.red.com/cwr/boids.html>

Boids Video

GAMEDevelopers

...boids video...

Steering-Based Hockey Simulation

GAMEDevelopers

Basic Hockey Player

GAMEDevelopers

- Physical model
 - point mass
 - limited force and velocity
 - collision modeling (as cylinder)
- Awareness of
 - position and velocity of players and puck
 - position of rink and markings
- Behaviors:
 - avoid rink walls and goal nets
 - chase loose puck, skate towards location...
- Assigned role
(forward, wing, defenseman, goalie)

Hockey *Role* Model

GAMEDevelopers

- Defenseman
 - if you have the puck...
 - if your teammate has the puck...
 - if puck is within your zone:
 - discourage shot on goal
 - discourage pass to opponent
 - don't crowd goalie
 - do basic hockey play stuff

Hockey Demo

...hockey demo...

Evolution of Behavior

Evolution of Behavior

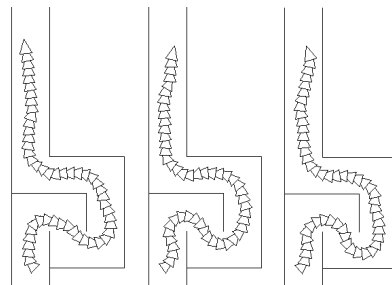
- Agent in simulated world
- Evolution of
 - behavioral controller
 - agent morphology (see Sims SIGGRAPH 94)
- Fitness based on agent's performance
 - objective fitness metric
 - competitive fitness

Corridor Following

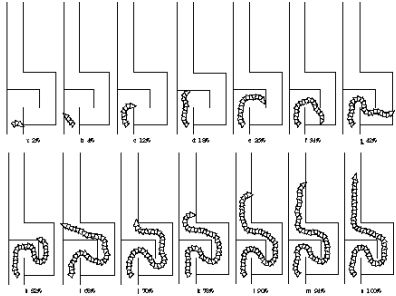
Evolution of Corridor Following Behavior in a Noisy World

- Evolve controller for abstract vehicle
- Task: corridor following
 - noisy range sensors
 - noisy steering mechanism
- Evolution of sensor morphology

Corridor Following: goal



Corridor following: fitness



Corridor Following: Results

- Works well
- Difficulty strongly related to the representation used
- “Competent” controllers easy to find
- Reliability of controllers is difficult to measure

Corridor Following: Experimental Design

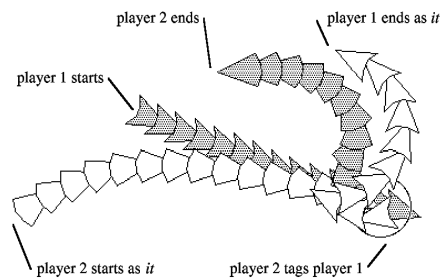
- Vehicle model
 - constant speed
 - limited steering angle
 - noisy sensors (arbitrary number & direction)
 - noisy steering mechanism
- Genetic Programming
 - hybrid steady-state model
 - worst of four noisy trials
 - population: 2000
 - size limit for evolved programs: 50

Coevolution of Tag Players

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

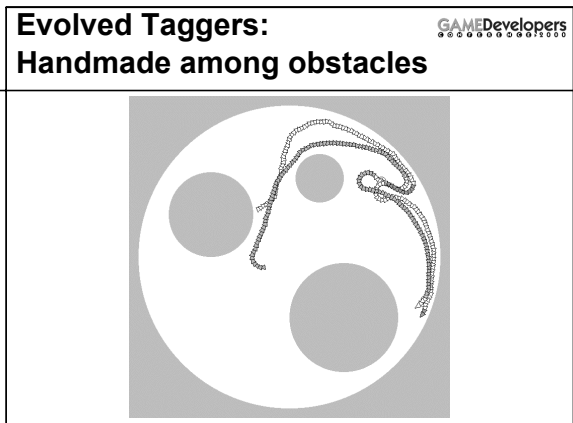
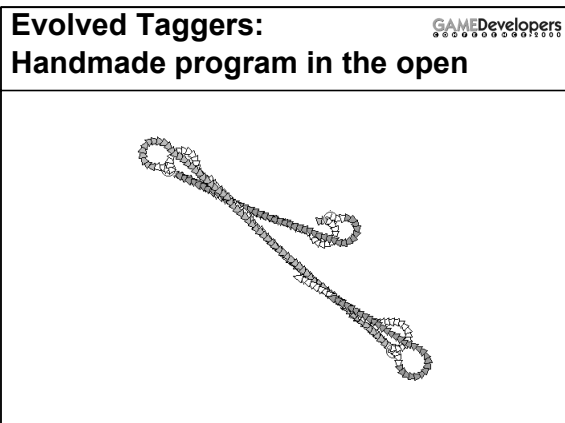
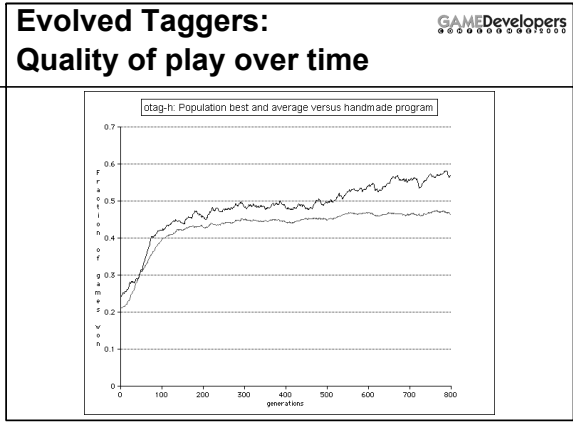
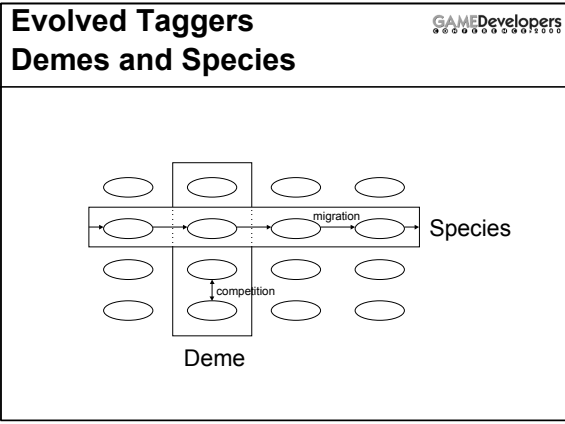
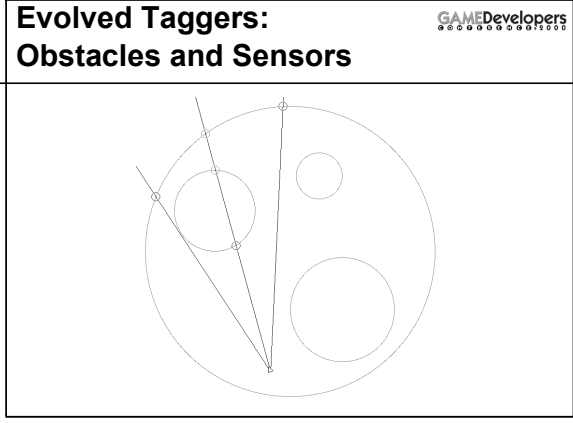
Competition, Coevolution and the Game of Tag (ALife IV, 1994)



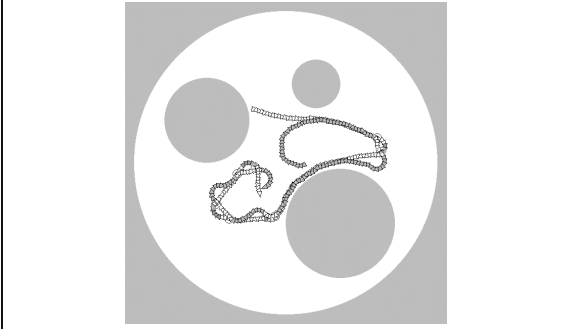
GAMEDevelopers

Coevolution of Taggers *Revisited*

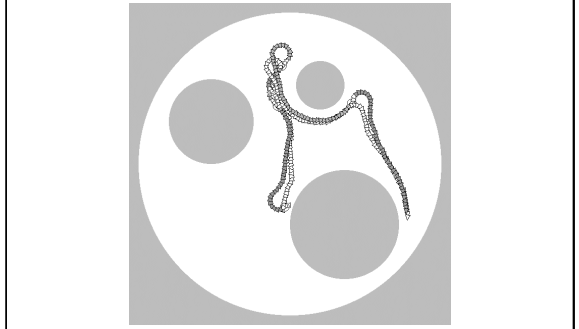
- December 1999 to present
- Similar to 1994 work, but:
 - longer games (25→150)
 - steering angle limits
 - obstacles and sensors
 - demes and species
 - improved performance
(faster computers, compilation of evolved programs)



Evolved Taggers: GAMEDevelopers
Typical competitive fitness test



Evolved Taggers: GAMEDevelopers
Typical competitive fitness test



Coevolution of Tag Players: GAMEDevelopers
Results

- It works! (after a lot of tweaking)
- An ecology of competing behaviors did arise
- Originally, evolved behaviors had been sub-optimal (perhaps do to *collusion*: “live and let live”)
- Finally (after demes, species, and harsh penalties) the evolved tag players have exceeded the quality of play of my hand-crafted player.

Conclusion GAMEDevelopers

- Autonomous characters:
 - add richness and complexity to virtual worlds
 - automate creation of groups and crowd scenes
 - allow life-like improvisational action
 - can react to unanticipated situations, like user input
- Games and animation provide many applications of, testbeds for, and problems to be solved by research in:
 - artificial life
 - artificial intelligence
 - evolutionary computation
 - and other biologically-inspired methods

