Reactive Autonomous Characters

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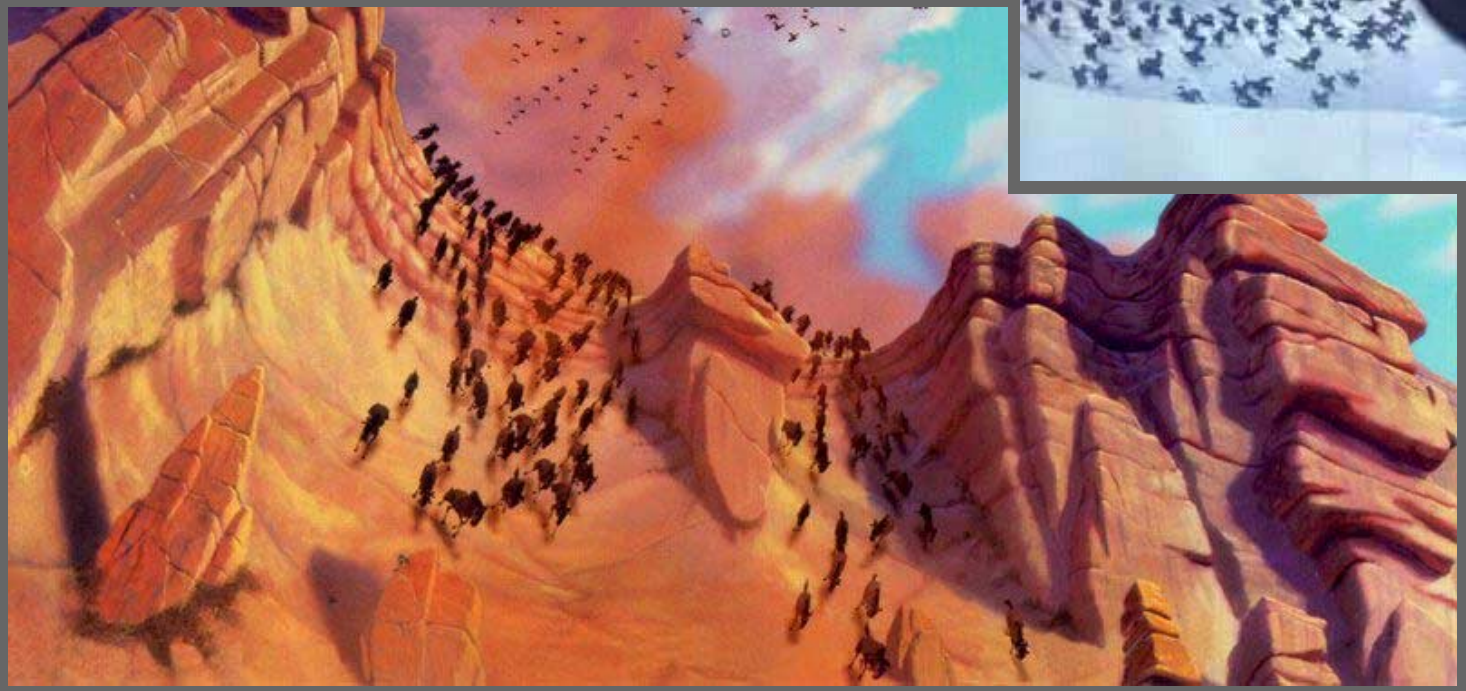
In this talk

- Generally: autonomous characters
  - Definitions
  - Applications
- Specifically: steering behaviors
  - Toolkits
  - Procedural composition
  - Evolutionary computation

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

© 2000 Blizzard Entertainment

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Autonomous characters: applications

- Animation for film, TV and other *linear media*
  - Known as "behavioral animation"
  - Primarily used for large crowd scenes
    - Groups of humans, animals, vehicles
    - Background action
- Games, VR and other *interactive media*
  - Known as "non−player characters"
    - Opponents
    - Allies
    - Background characters

Autonomous characters: groups

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

Autonomous characters: advantages

- Linear media
  - Provides labor savings over animating each character
  - But result *on the screen* is the same
- Interactive media
  - Characters must react to unpredictable human player
  - Believable characters require autonomy
- Interaction provides most compelling application

Autonomous characters: history

- First application in animation

  Stanley and Stella in Breaking the Ice (1987)

- Widely used in film now

  Batman Returns (1992), Cliffhanger (1993), The Lion King (1994), From Dusk Till Dawn (1996), The Hunchback of Notre Dame (1996), Hercules (1997), Spawn (1997), Starship Troopers (1997), Mulan (1998), Antz (1998), A Bugs Life (1998), The Prince of Egypt (1998), Star Wars: Episode I, The Phantom Menace (1999), Lord of the Rings trilogy (2001–2003), ...

Types of behavioral models

- Kinematic
- Dynamic
- 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

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 for animation production

- Obstacle avoidance
- Flocking
  - Separation
  - Alignment
  - Cohesion
- Attraction to (or repulsion from) a target

Stanley and Stella in Breaking the Ice

Real time flocks

Pigeons in the Park

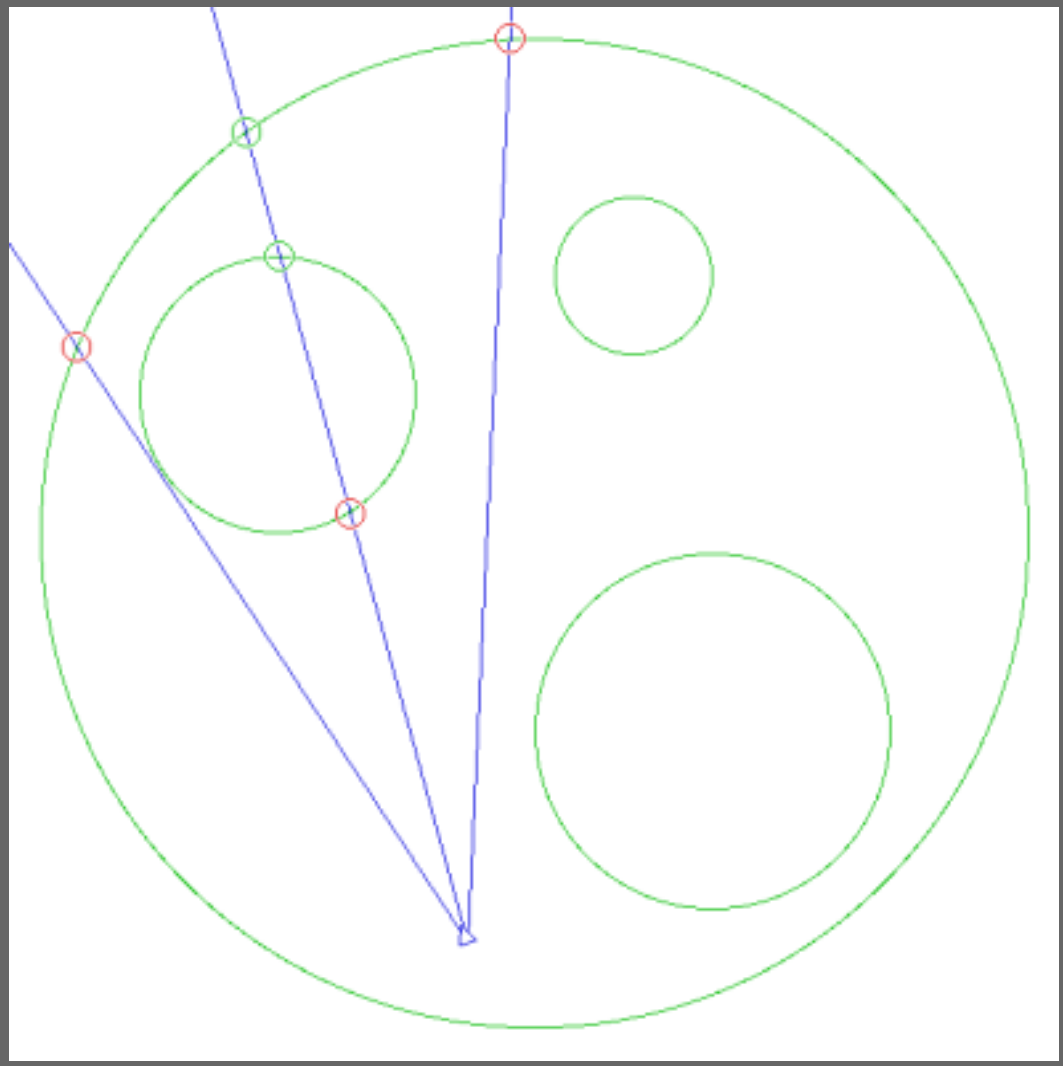
- Based on the 1987 boids model of flocks, herds and schools
- Uses fast hardware (PS2), and spatial data structures to accelerate boids: about 6000 times faster than in 1987.
- Allows real time (60 fps) interaction with a group of about 300 birds.
- Includes behavioral state transitions

Pigeons in the Park video

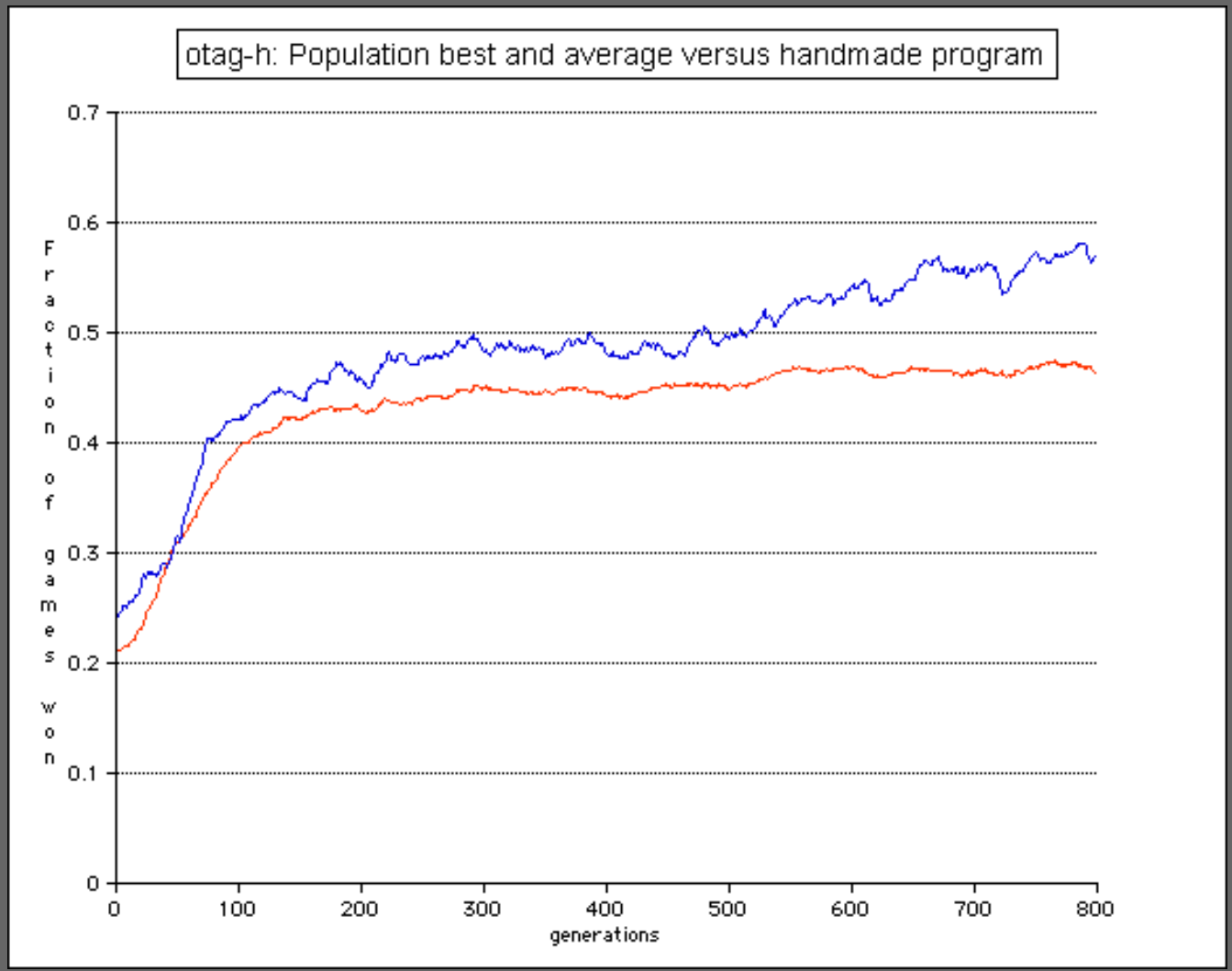
Coevolution of Tag Players

- 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

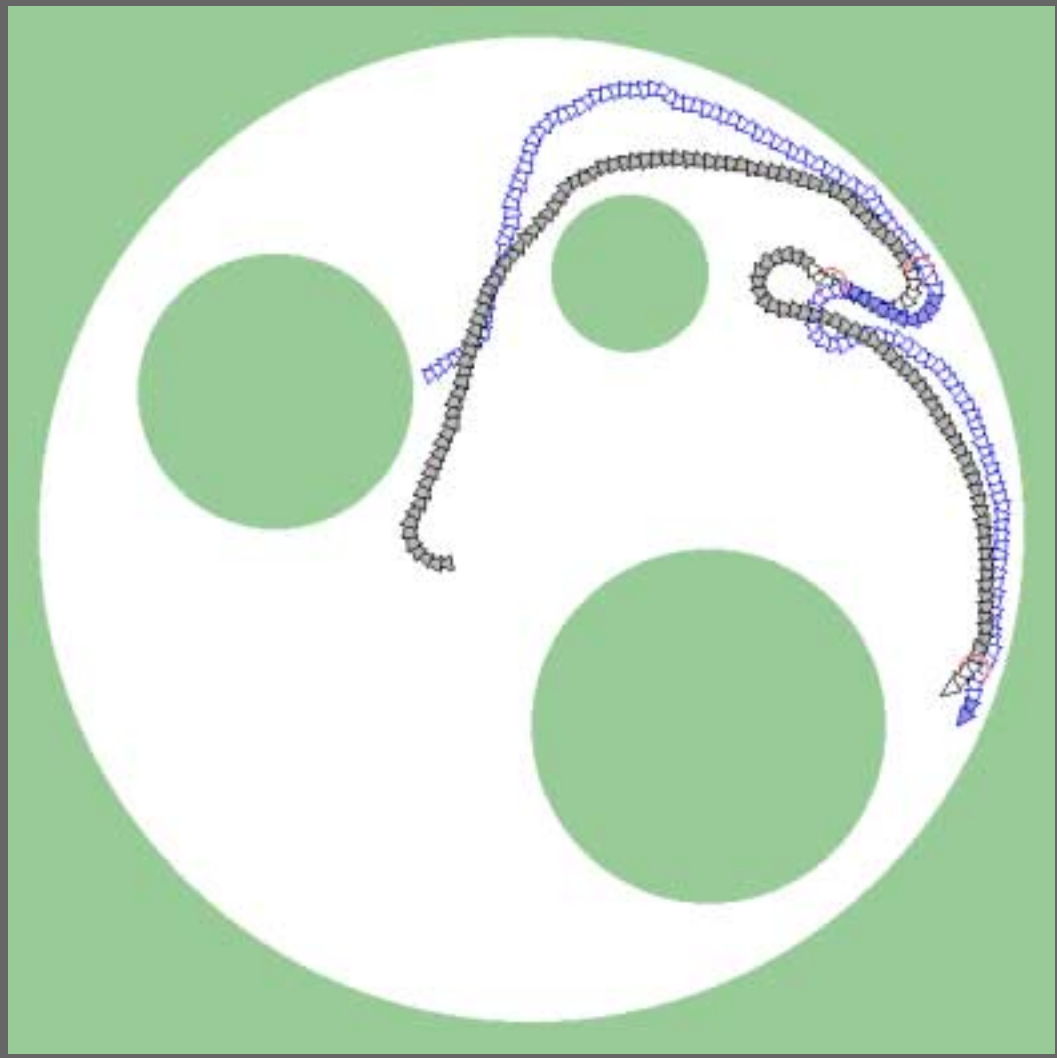
Sensors and obstacles



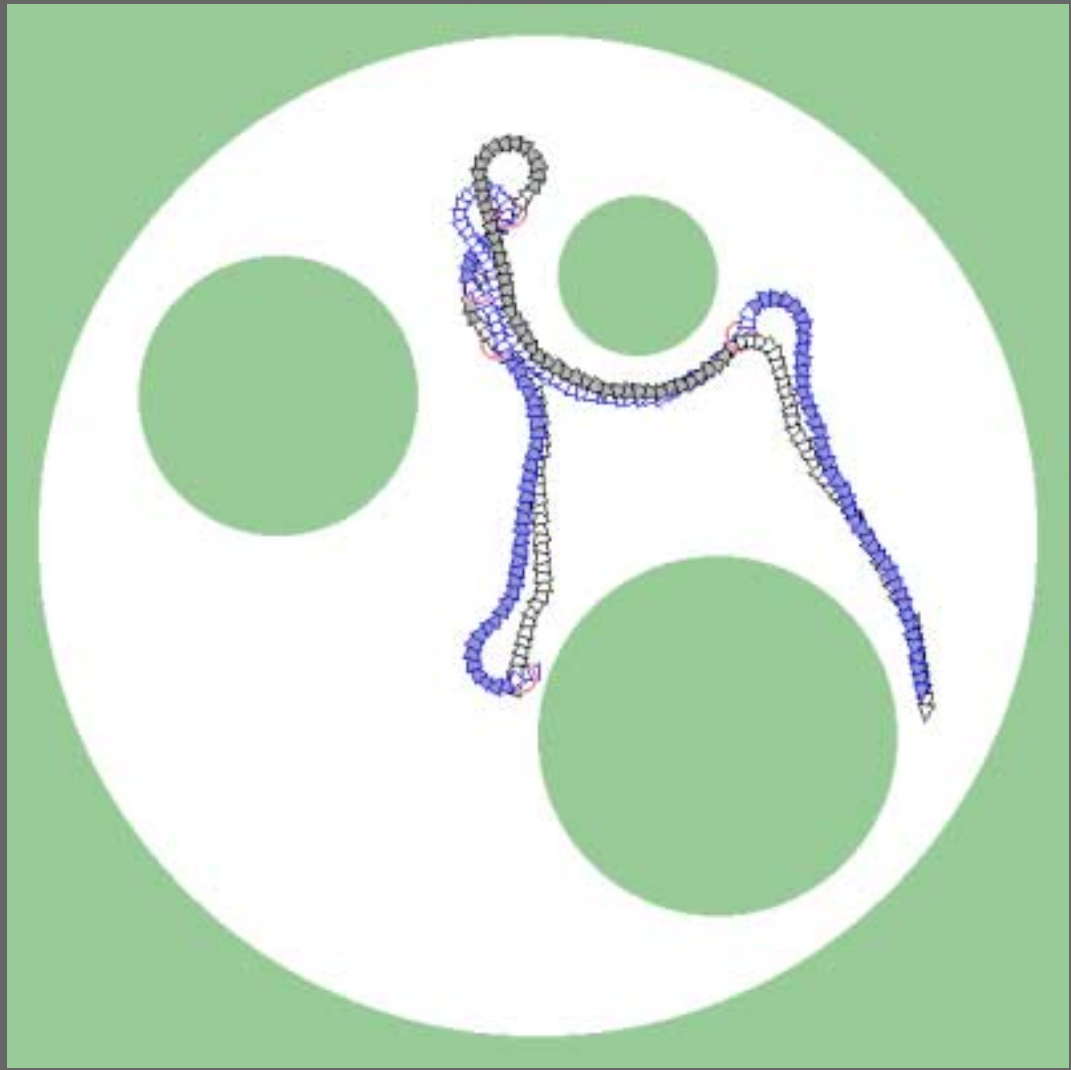
It works!


otag-h: Population best and average versus handmade program
Fraction of games won
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
generations

Typical fitness test (1)



Typical fitness test (2)



Competitive coevolution: summary

- Pros:
  - Can produce high quality players
  - Meets or beats human−designed players
  - 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.

Conclusions

- Autonomous characters
  - Definitions
  - Applications
- Steering behaviors
  - Toolkits
  - Procedural composition
  - Examples: hockey, boids, interaction
  - Evolutionary computation