Craig Reynold's
Steering Behaviors For Autonomous Characters
& related MetaCreations

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IAT 811 Computational Poetics

MetaCreation: Machines Endowed with Creative Behavior

Overview

1. **Who is Craig Reynolds?**

2. **Steering Behaviors for Autonomous Characters - 1999**
   - Definitions
   - What is Steering Behavior?
   - Related Scientific Work
   - The Basic Model
   - Description of Steering Behaviors Types
   - Boids in Depth
   - OpenSteer Demonstration

3. **Boid Metacreations for Further Discussion**
   - Starlings on Otmoor (Natural Phenomena)
   - Ecosystm, John Klima - 2000
   - Swarm, Daniel Shiffman - 2003

4. **Ending Remarks & Discussion**

Who is Craig Reyolds?

1. **Homepage** http://www.red3d.com/cwr/

2. **His own words…**
   - *"Computer modeling of life-like complex behavior is my main area of interest. I write software to simulate various types of human and animal behavior, mostly related to an autonomous character's motion around its simulated world. In addition to some pure research, my work involves applying these models to production of feature films and these days, and games. I am also interested in using evolutionary computation to design procedural models, such as behavioral controllers, according to aesthetic criteria."*

3. **Academic**
   - Graduate of **MIT** The Architecture Machine Group (now part of The Media Lab)
   - Numerous publications in **Computer Graphics, Artificial Intelligence, and Autonomous Characters**

4. **Professional**
   - Currently works at the US R&D group of **Sony** Computer Entertainment
   - Past: DreamWorks Animation, Electronic Arts, scene programmer for **TRON**
   - 1998 **Academy Award** recipient for pioneering contributions to the development of three dimensional computer animation for motion picture production

Definitions

- **Behavior**
  - Behavior refers to the actions or reactions of an object or organism, usually in relation to the environment.
  - The term behavior is used to refer to the improvisational and life- like actions (or motions) of an autonomous character

- **Autonomous Agent**
  - is a system situated in, and part of, an environment, which senses that environment, and acts on it, over time, in pursuit of its own agenda. This agenda evolves from drives (or programmed goals). The agent acts to change the environment and influences what it senses at a later time.
  - Non-biological examples include intelligent agents, autonomous robots, and various software agents, including artificial life agents, and many computer viruses.
  - An autonomous character in games must combine aspects of an autonomous robot with some skills of a human actor in improvisational theater. These characters are usually not real robots, and are certainly not human actors, but share some properties of each.

- **Artificial Life**
  - Commonly Alife is a field of study and an associated art form which examine systems related to life, its processes, and its evolution through simulations using computer models, robotics, and biochemistry.

What is Steering Behavior?

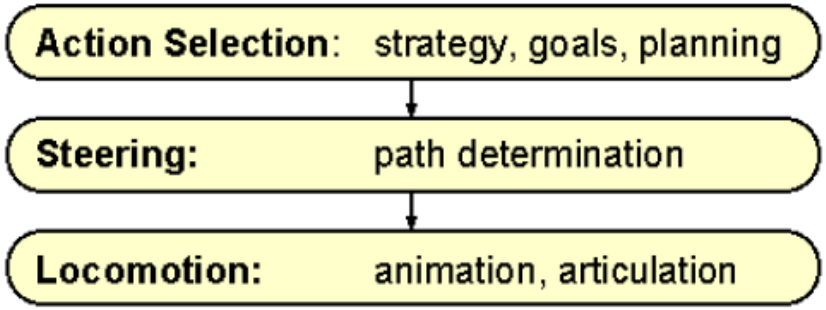


Figure 1: A hierarchy of motion behaviors

- *"This paper will focus on Steering, the middle layer of the behavioral hierarchy. It will briefly describe a simple model of the locomotion layer, but only in enough detail to provide a concrete foundation for the discussion of various steering behaviors. There will be some brief discussion of action selection, but primarily in the context of combining and blending basic steering behaviors."*

- Steering behaviors must anticipate the future and take into account eventual consequences of current actions.

- Emergent life- like behavior are the results

Related Scientific Work

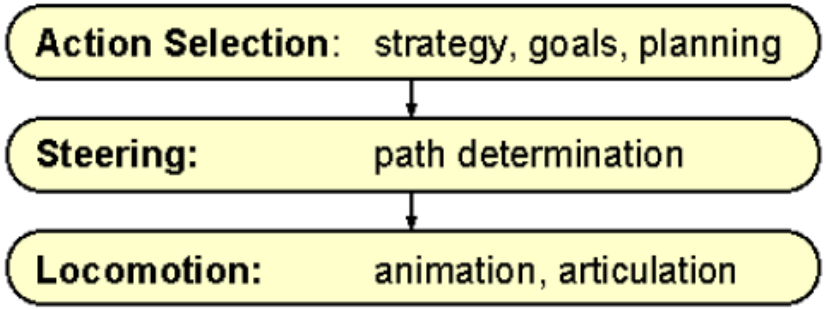


Figure 1: A hierarchy of motion behaviors

- **Robotics**
  - Reactive controllers for mobile robotic systems (Rodney Brooks)
- **Artificial Intelligence**
  - Generated animation of character motion from story descriptions (Ken Kahn)
  - Emotional, improvisational, dramatic characters, which touches on steering behavior (Project Oz by Joseph Bates et al)
- **Artificial Life**
  - Boids, developed by Craig Reynolds in 1986, is an artificial life program, simulating the flocking behavior of birds
  - Evolved Virtual Creatures by Karl Sims
  - Behavioral scripting locomotion & action selection (Ken Perlin & Athomas Goldberg)
  - Human Crowd simulation

The Basic Model

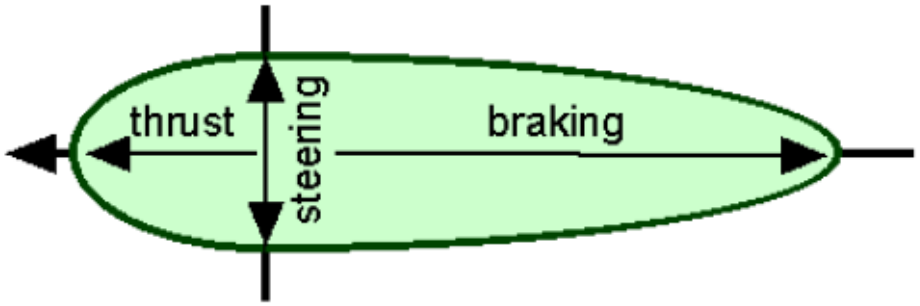


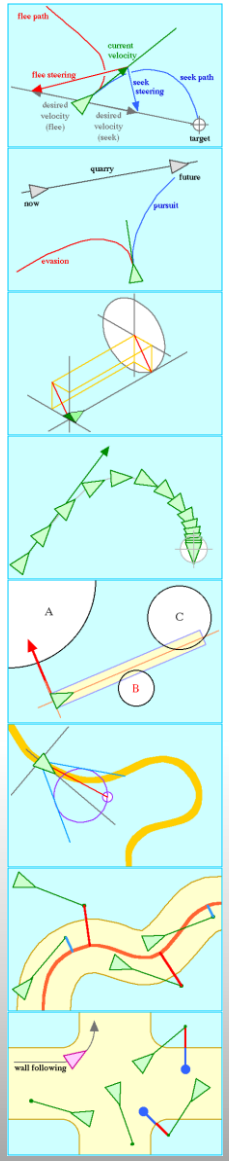
Figure 2: asymmetrical steering forces

position vector
velocity vector
max_force scalar
max_speed scalar
orientation N basis vectors

- In order to remain aligned with velocity at each time step, the basis vectors must be rotated into a new direction. The local space is reconstructed using a combination of substitution, approximation, and re-orthogonalization

steering_force = truncate (steering_direction, max_force)
acceleration = steering_force / mass
velocity = truncate (velocity + acceleration, max_speed)
position = position + velocity

Description of Steering Behaviors



Seek and Flee

- Steer the character towards a specified position in global space. Flee is the inverse

Pursuit and Evasion

- Pursuit is similar to seek except that the quarry (target) is another moving character.
- Evasion is analogous to pursuit, except that flee is used to steer away from the predicted future position of the target character.

Offset Pursuit

- Steering a path which passes near, but not directly into a moving target

Arrival

- Arrival behavior is identical to seek but instead of moving through the target at full speed, this behavior causes the character to slow down as it approaches the target, eventually slowing to a stop coincident with the target.

Obstacle Avoidance

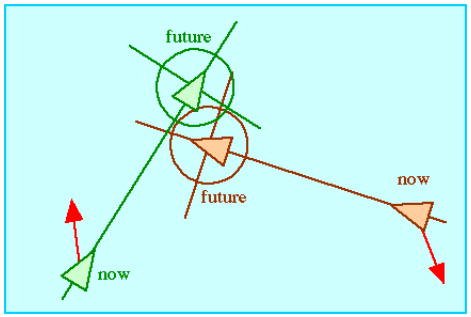
- The ability to maneuver in a cluttered environment by dodging around obstacles.

Wander

Path Following

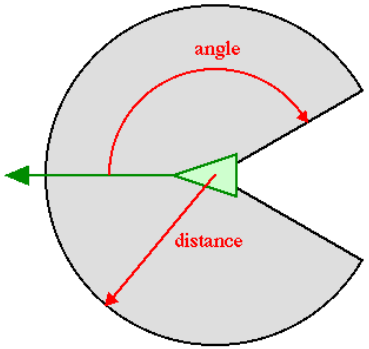
Wall following and Containment

Description of Steering Behaviors - Boids



Unaligned Collision avoidance

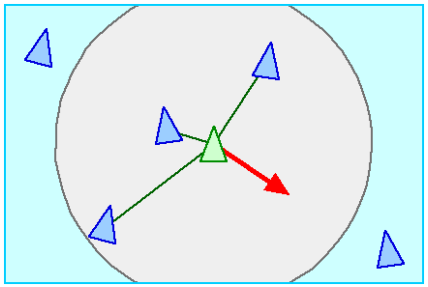
- behavior tries to keep characters which are moving in arbitrary directions from running into each other.



Local Neighborhood

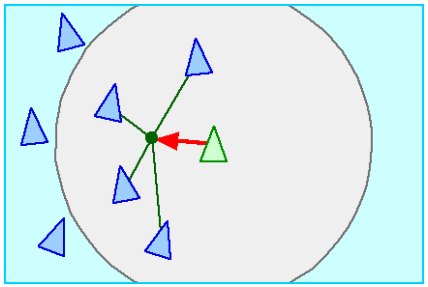
- Pursuit is similar to seek except that the quarry (target) is another moving character.
- Evasion is analogous to pursuit, except that flee is used to steer away from the predicted future position of the target character.

Description of Steering Behaviors - Boids



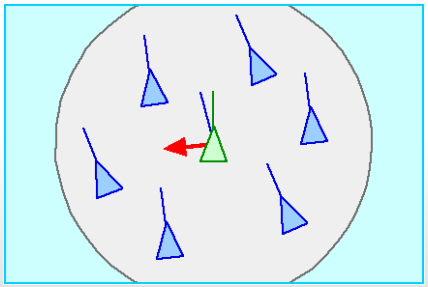
Separation

- The ability to maintain a certain separation distance from others nearby.



Cohesion

- The ability to cohere with (approach and form a group with) other nearby characters



Alignment

- The ability to align itself with (that is, head in the same direction and/or speed as) other nearby characters,

Opensteer Demonstration

http://opensteer.sourceforge.net/

- OpenSteer is a C++ library to help construct steering behaviors for autonomous characters in games and animation. In addition to the library, OpenSteer provides an OpenGL-based application called OpenSteerDemo which displays predefined demonstrations of steering behaviors. The user can quickly prototype, visualize, annotate and debug new steering behaviors by writing a plug-in for OpenSteerDemo.

Boid MetaCreations for Further Discussion

Starlings of Otmoore

http://ca.youtube.com/watch?v=XH-groCeKbE&feature=related

Where

- Near Oxford England, flat marshland environment (reed and open water) away from hills where there is more steady **“avian motorways”**

When

- Winter evenings only

What

- Otmoor is a Haven for wild birds. The spectacle is referred to as “Incredible and bizarre display of aeronautical skill” & “seemingly pointless”

How

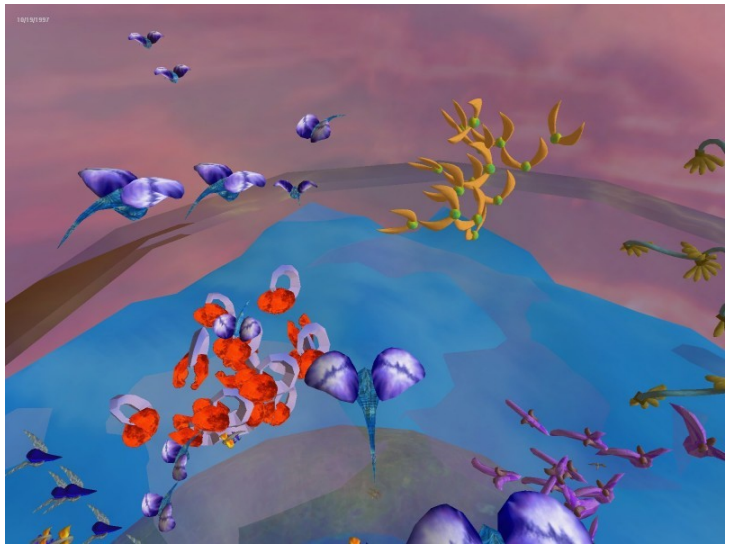
- Starts out as small Foraging & feeding groups during the day that gather in masse in the evening

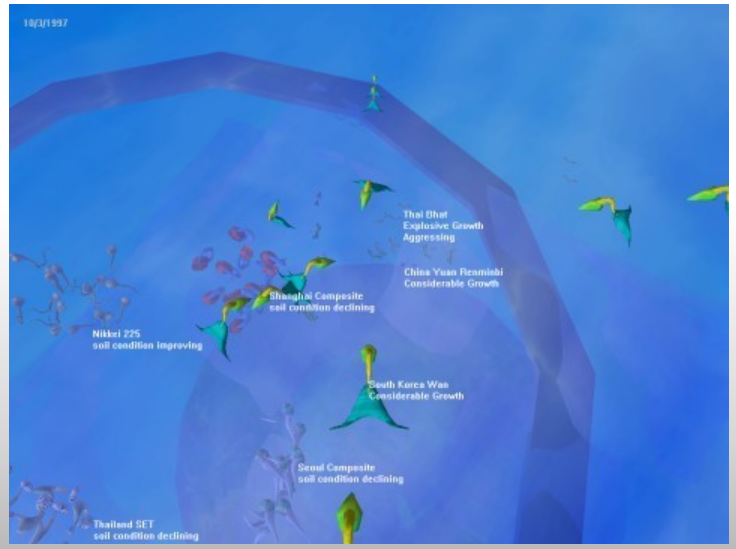
Why

- **Defense:** Thousands of eyes to watch for predators
- **Survival:** Activity warms their bodies for the cold night ahead
- **Social Positioning**: Dominant males get the best and safest perches afterwards. Females and adolescents stay nearby

Boid MetaCreations for Further Discussion

EcoSystm, John Klima





http://www.cityarts.com/ecosystm/

Where

- Takes place in a symbolic 3D virtual world at an investment bank

When

- Continuously - from real-time investment data

What

- Ecosystm is a real-time representation of **global currency volatility** (daily and annual) fluctuations, leading global **market indexes**, and up-to-the-minute **weather reports** from JFK airport
- Ecosystm consists of flocks of "birds" (each flock representing a country's currency) and branching "tree" structures (each tree representing a country's leading market index). As a market index advances, the tree grows new branches. If the index declines, branches begin to fall off the tree

How

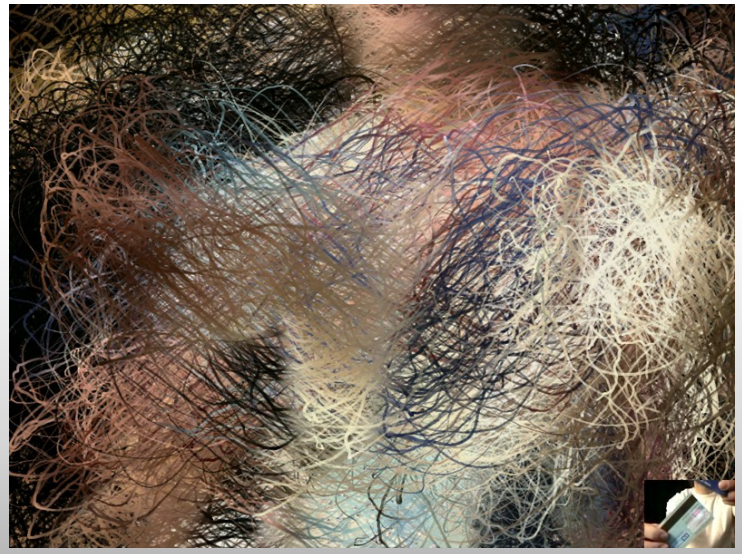
- Daily and annual volatility determines the territory the flock occupies. If a currency is stable, the flock has an expansive territory and can fly throughout it in a graceful manner. If, however, the currency is volatile, the flock becomes very "excited", and their available territory is considerably reduced in size

Why

- The flocks exhibit certain behavioral patterns determined by the volatility of their currency. **Volatility is a common financial analysis equation that examines values over time periods**.

Boid MetaCreations for Further Discussion

Swarm , Daniel Shiffman



Where

- A 2D display in a museum

When

- Only when a viewer comes close to the camera

What

- An interactive video installation that implements the pattern of flocking birds using Craig Reynold's "Boids" model as a **constantly moving brush stroke**.

How

- Taking inspiration from Jackson Pollack's "drip and splash" technique of pouring a continuous stream of paint onto a canvas, Swarm **smears colors** captured from live video input, producing an organic painterly effect in real-time

Why

- Shiffman wanted to develop a program that would "paint" an abstracted screen portrait of whoever was in front of the display, slowly repainting and revising the picture as the viewer moved
- **"you are the one being awesomely manipulated, blown apart and put back together"**

http://www.shiffman.net/projects/swarm
http://www.nytimes.com/2003/11/16/arts/design/16BAYL.html?ex=1205435601&ei=1&en=577a9e2812631145

Ending Remarks & Discussion

Proof of Concept

- Synergy : Hierarchy of Motion Behaviors
  - **Action Selection:** strategy, goals, planning
  - **Steering:** path determination
  - **Locomotion:** animation, articulation

Real World Example

- Highly specific time and place of behavioral occurrence
- Purposeful behavior (defense, Survival, and Social Hierarchy)
- Situated in the real world

Data Driven Visualization

- Emphasis on Action Selection and Steering
- Behavior is an outcome of re-mapping information into a new Ecology
- Situated Virtually

Painterly

- Emphasis on Locomotion (shape & movement), there is not that much higher intelligence
- Augmented situation
- Viewer ascribes own interpretation (reflective)