Group Behaviors

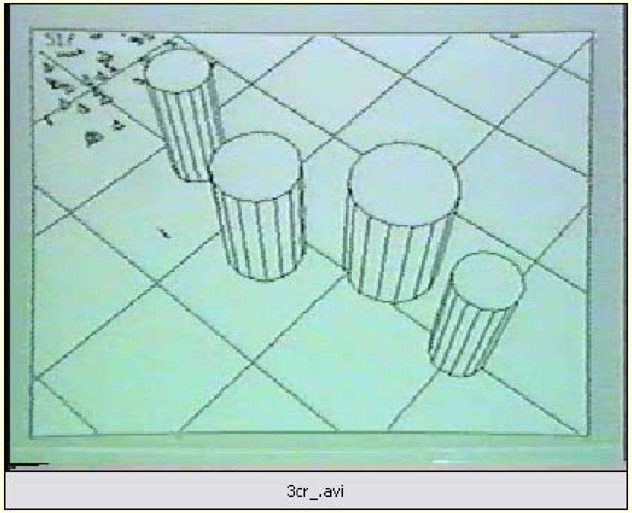
- Motivation, Group/Crowd
- Procedural Animation – Boids Model
  - Particle Systems
  - Physical Dynamics
- Example – *AI implant* system
- Example – Real Time Strategy game
- Other examples

Sources

- Reynolds, Boids Model, http://www.red3d.com/cwr
- Game Developers Conference, and Gamasutra articles
- Bouvier et al., Heigeas et al., Particle Systems
- Hodgins and Brogan, Physical Dynamics
- Biographics Technologies, *AI implant*
- Pottinger, papers about crowds in “Age of Empires”

Motivation

- Automate motion of individuals in large group



Group/Crowd

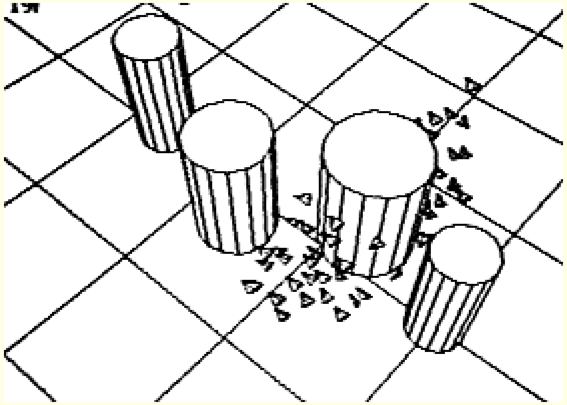
- Large group of individuals in same physical environment
- Common goal
- May act in different way than when they are alone
- Variety in individuals (not clones of each other), but still relates to group
- Games: Fast; tradeoff for realistic motion

Possible group behavior

- Seek goal position
- Flocking
- Dispersion/Aggregation
- Following leaders
- Collision avoidance

Procedural animation

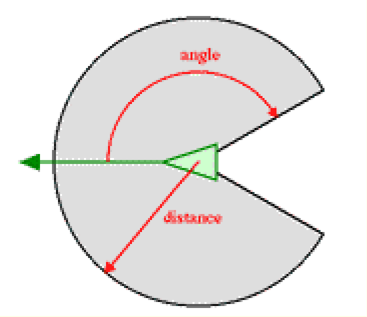
- initial state of objects in system, rules for updating, states for subsequent step based on conditions in previous step



Procedural animation

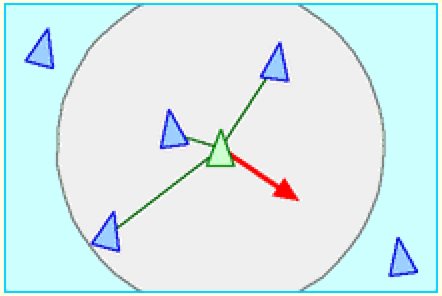
- Useful for generating lifelike motion with relatively little input
- But lack of explicit control over look of individual frames

Boids model – vehicle model

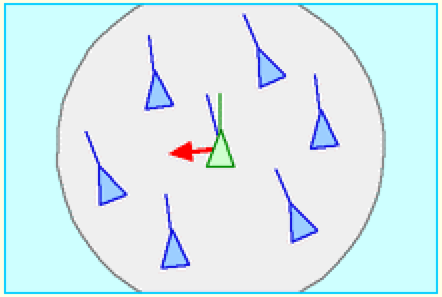


- Mass, position, velocity, max force, max speed, orientation

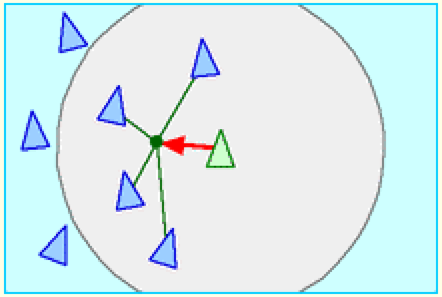
Boids model – 3 Rules



Separation: steer to avoid crowding local flockmates



Alignment: steer towards the average heading of local flockmates



Cohesion: steer to move toward the average position of local flockmates

Boids model

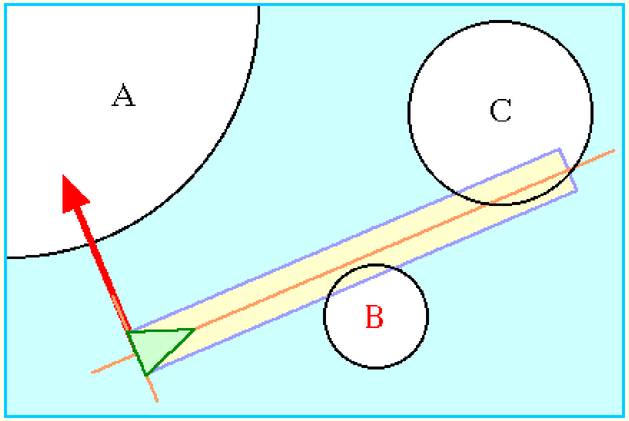
- 3 rules are necessary, and also sufficient based on experimental results – Video

Boids Model

- Complex behavior from simple rules
- Rules applied to individuals → lead to global behavior (emergence)

- Demo – Flocking http://www.red3d.com/cwr/steer/

Obstacle avoidance

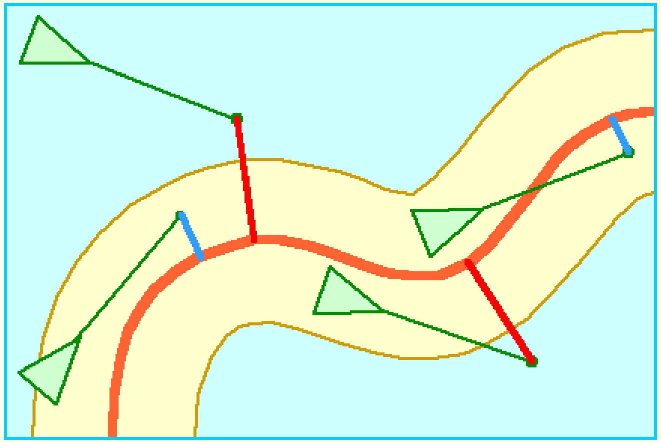


- Additional rule
- Demo – Obstacle Avoidance, Unaliged obstacle avoidance

Half-Life and Unreal

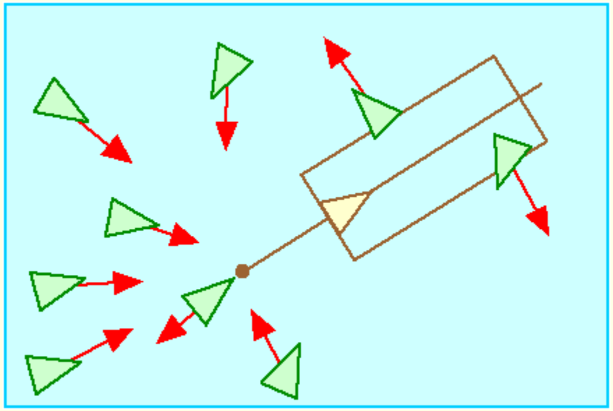
- "With the proper flocking routines in place, enemies hunt in packs, cover each other, and generally act like they place some value on both their own lives and the lives of their comrades." [Gamasutra article]

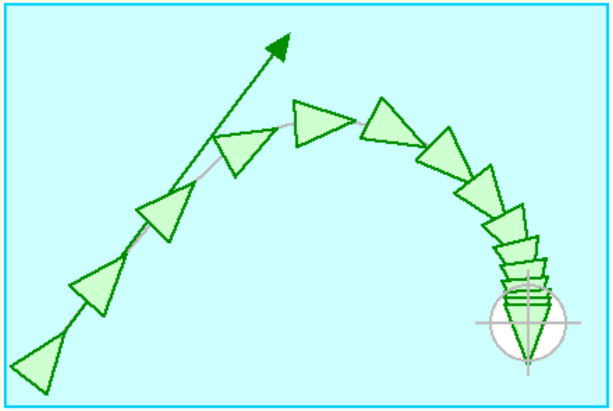
Path Following



- Predict future position, project onto path, steer towards path if necessary
- Approach and then follow path
- Demo – path following, crowd path following

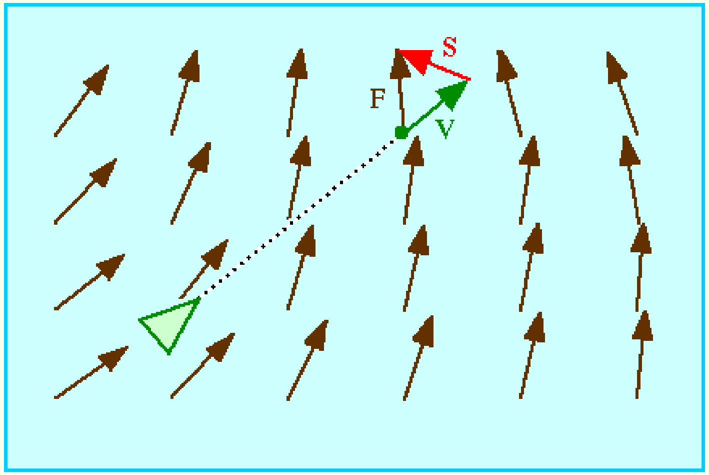
Leader Following





- Followers – stay near leader, but do not crowd leader, and move out of way
- Requires “Arrival” behavior – steers toward target, and slowing down along way

Flow field following



- Predefined flow field – maps to flow vector
- Steers towards flow vector
- Can be specified by artist (non-programmer), by painting general direction

Queuing through a narrow doorway

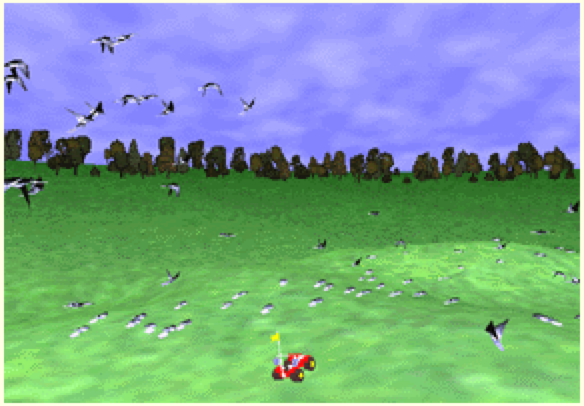
- Combination of seeking and decelerating
- Avoiding wall and each other

- Demo - Queuing

Combine these rules

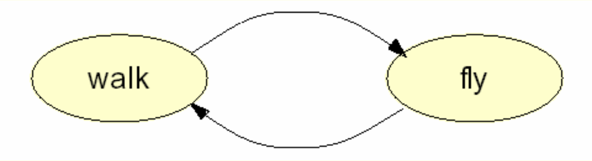
- Combine in different ways to get more complex behaviors
- Contradictory rules – need to prioritize them

Real-time interaction



- Environment with user-controlled car and birds (following 3 rules)
- PS2 – with 280 birds, 60 Hz

Finite-State Machine for birds



- Default behavior is *walk*
- Transition to *fly* if
  - Car comes close
  - Nearby birds *fly*
  - Loud noise nearby
- Stay at *fly* if car or loud noise keeps “annoying” it

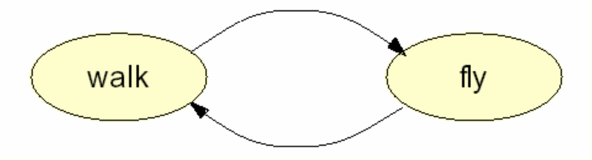
Birds – annoyance value

- “Annoyed” first time – fly short distance away, then land again
- Annoyance value goes up every time, but slowly decays
- Together with flocking rules and obstacle avoidance

Bird motion

- Generated from small set of pre-animated cycles, and parameters like character’s position and *walk/fly* state

- *Walking*, *Flying*, *Gliding*, and *WingFold*

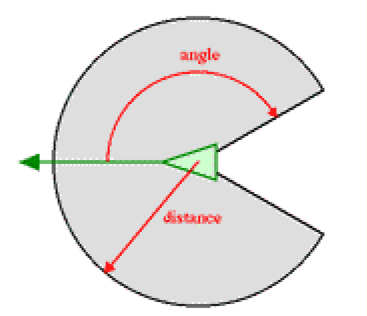


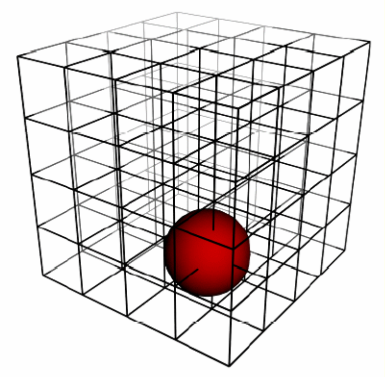
Optimization 1

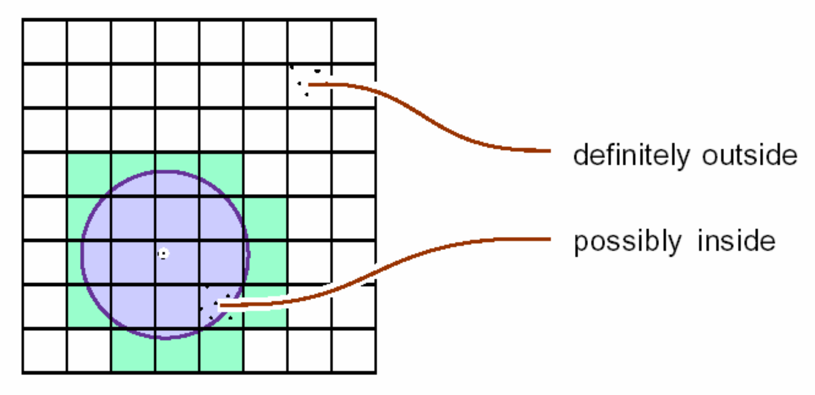
- Simulation is 60 Hz, but control program runs at 10 Hz
- Apply rules once every 6 simulation steps
- Between these steps, use same steering velocity

- For variety, phase of these cycles randomized for each bird

Optimization 2





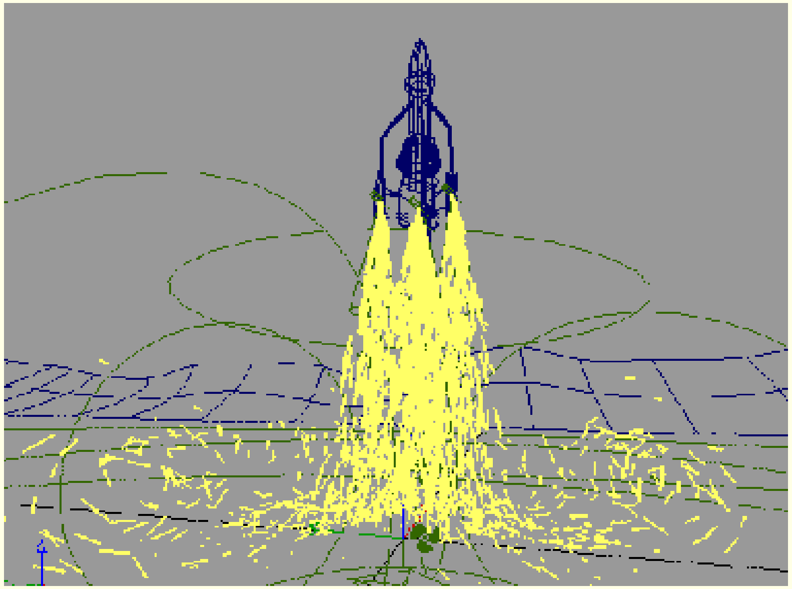


- □ Have to find the neighbors – $O(n^2)$
- □ Max number of bird k in each square – $O(nk)$, or $O(n)$

Video

Particle Systems

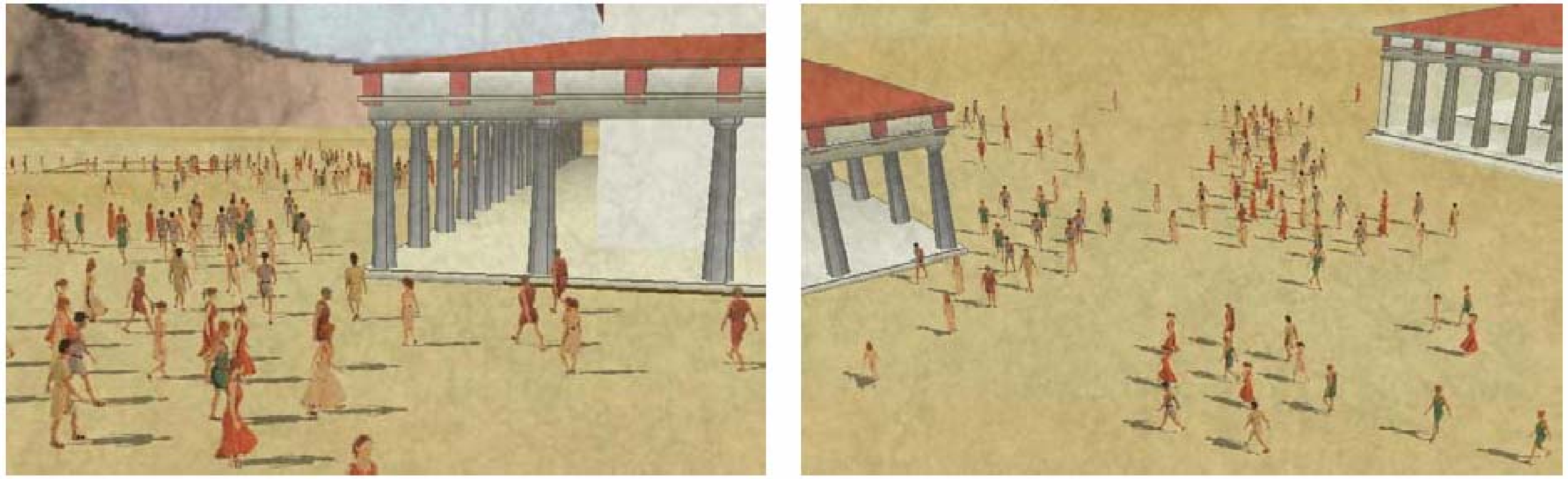
- Multiple particles in each frame or time step
- Rules for updating them based on particles (velocities, diffusion properties, lifespan) and forces (gravity, wind)
- Often used for clouds, water, fire



Particle System → Crowd

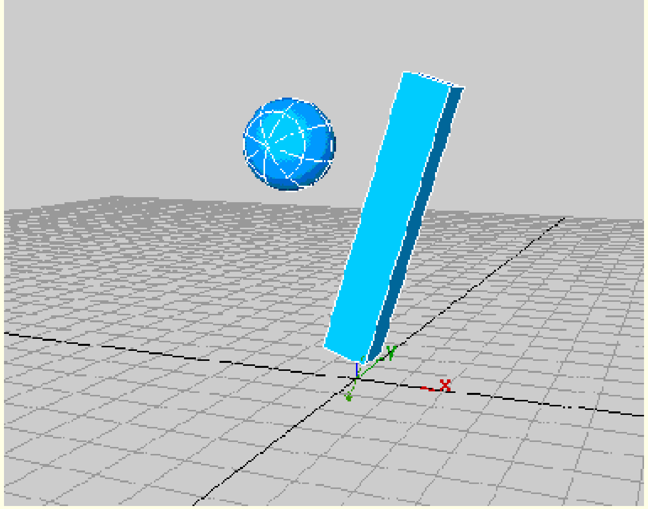
- Human beings modeled as interacting set of particles
- Forces of attraction/repulsion between particles and/or objects in scene
- Masses of particles can be those of individuals
- Attraction forces of certain groups of people can be higher/lower

Example crowd



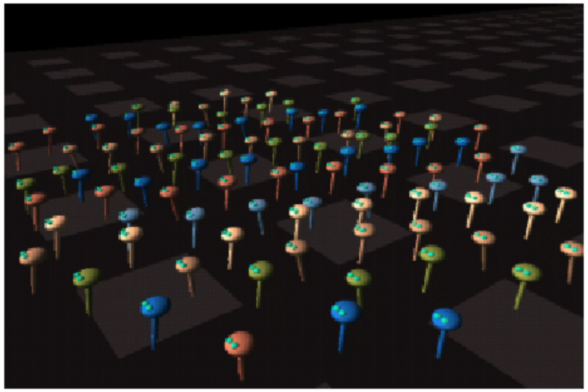
Physical Dynamics

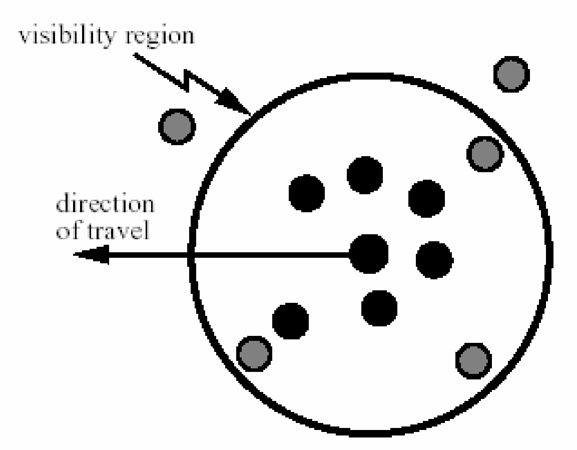
- Assign properties to objects (mass, resilience) and environment (gravity, density of air)
- Initial state
- Update rules

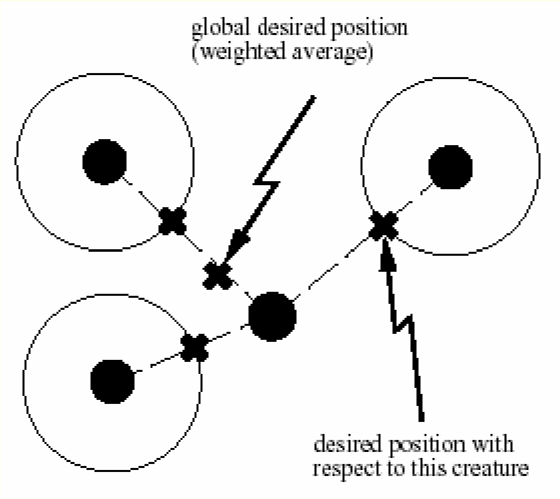


Physical Dynamics

- For each creature:
  - Find visible creatures
  - Calculate desired position and velocity (spring/damper)

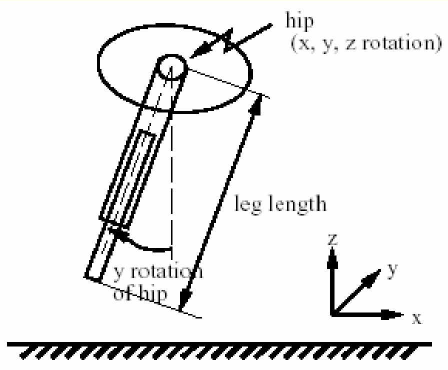





global desired position (weighted average)
desired position with respect to this creature

Physical Dynamics

- Equations of motion for rigid model of one-legged creature
- Given velocity → control algorithms generate motion for different speeds and flight durations

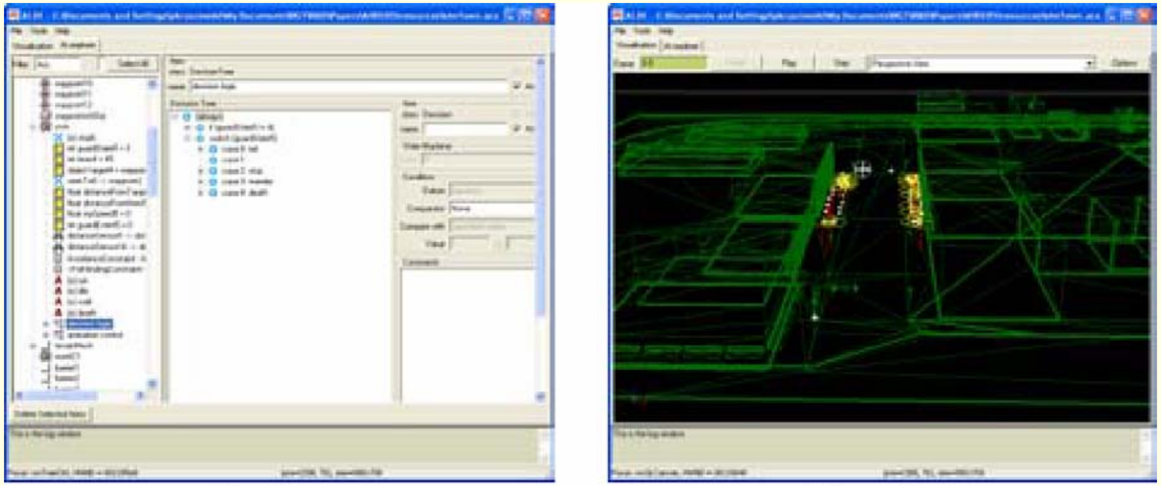


Example

- Avoid obstacle by aiming for point to the side of obstacle, and incorporate this into “desired position”
- Videos – 105HopFrontView/SideView

AI implant system

- Commerical system for real-time crowd simulation of people and vehicles
- Used for games in PS2 and Xbox



Explorer *Visualizer*

Screenshots of the AI development environment.

Navigation

- Navigation meshes

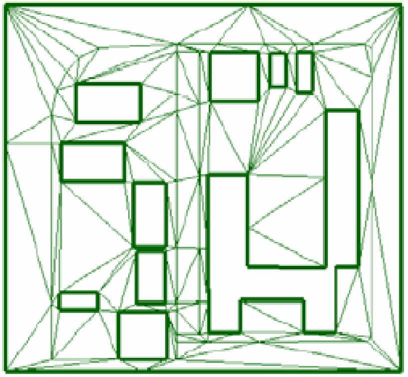
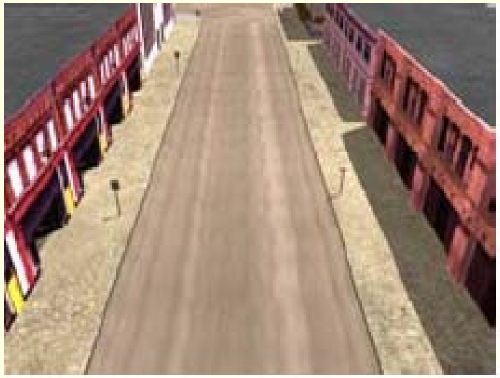
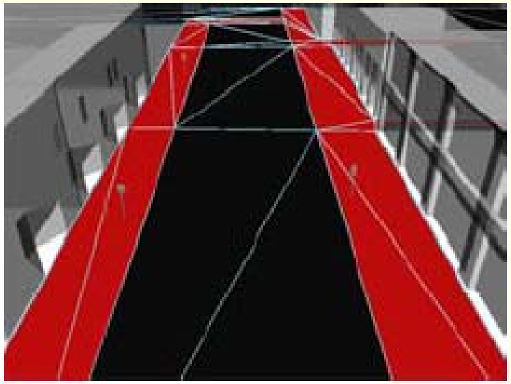


Figure 3. The navMesh corresponds to all navigable space (e.g., sidewalks and roads around buildings).





Reactive decisions

- Gather environment data during runtime and apply data to set of pre-defined rules (repath if something unexpected before happens)
- Animation system to control motion of humans/vehicles

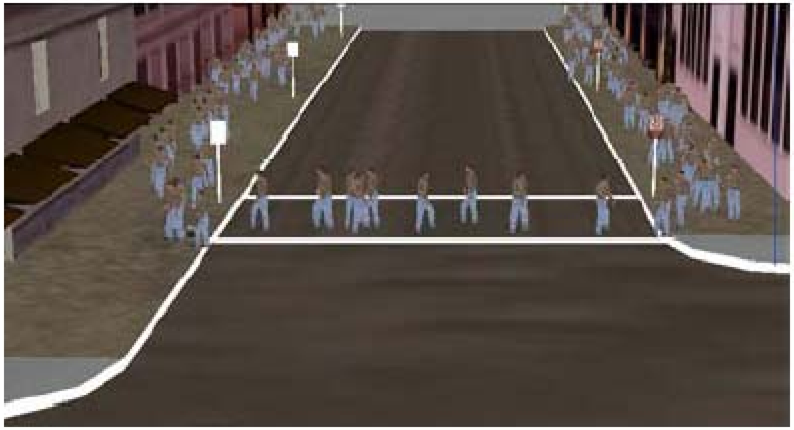
Crowd creation

- A few base templates of characters from which large numbers are instantiated
- Differentiated by parameters (animation control, reactive rules, mesh)

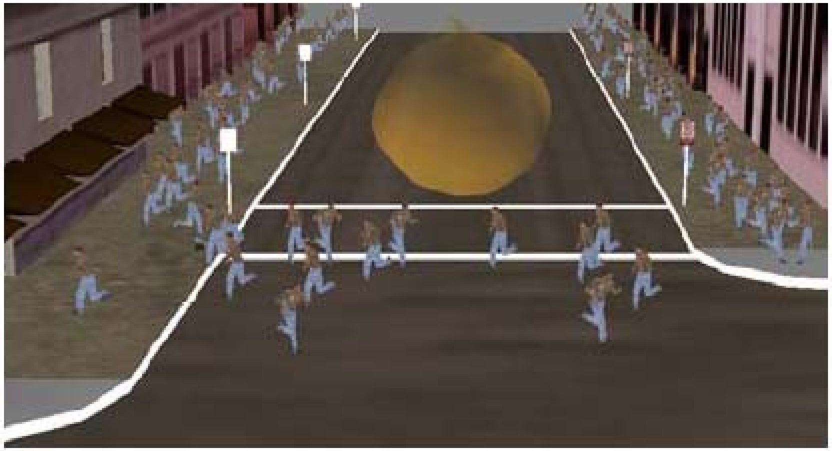
- Tool for artists to “paint” parameters or instantiation of many characters

Result scene

- Follow waypoints, can sense other characters, can slow down



Ambient milling behaviour: pedestrians staying on the sidewalk and crossing at the cross walk



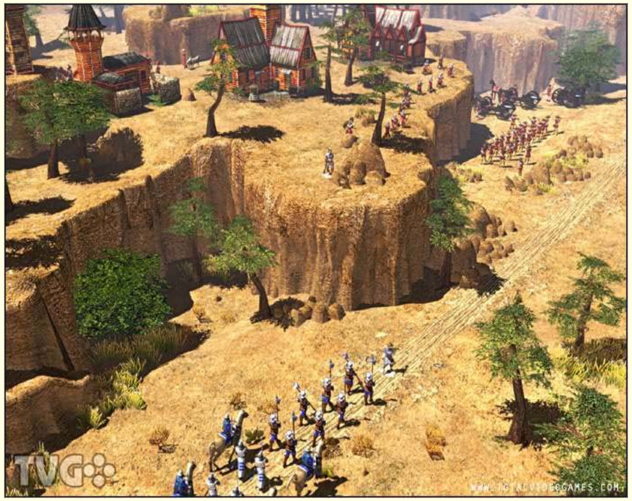
Panic behaviour: running away from traumatic event (orange ball).

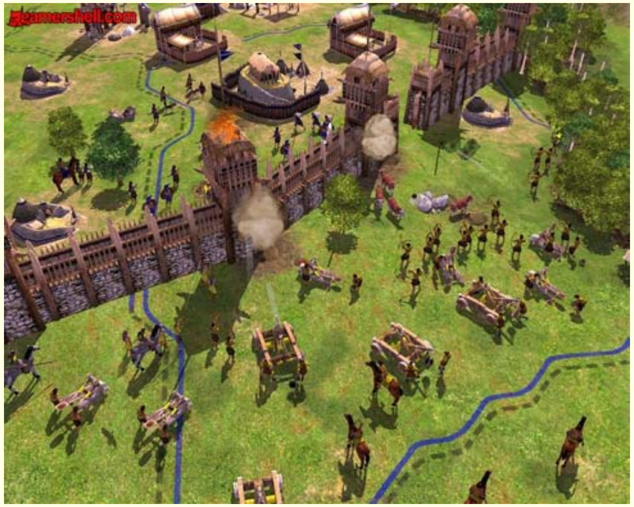
Videos

- PanicDemo640_480.mov
- raceTrack.mp4

Real-Time Strategy Games

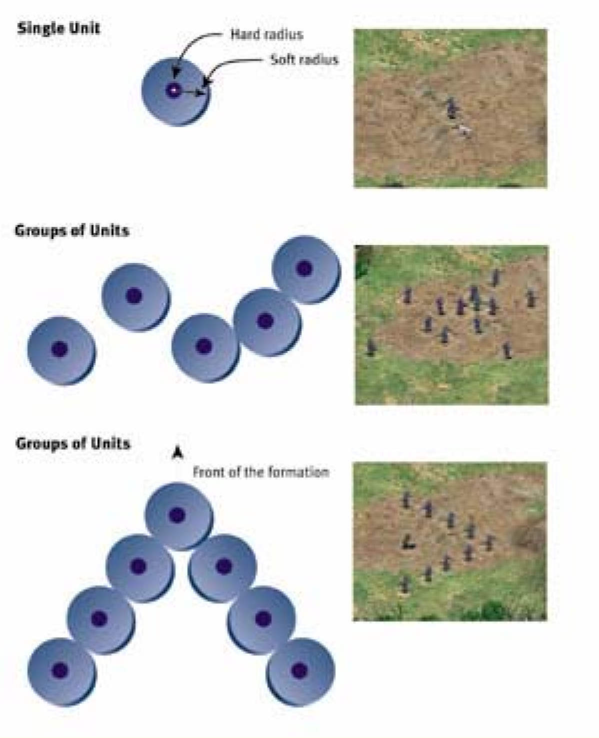
- Groups of characters





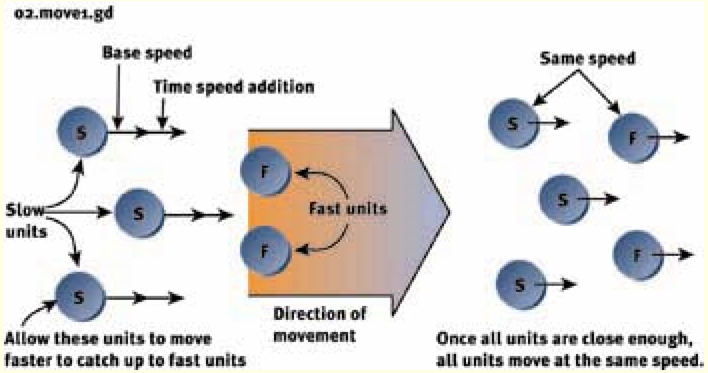
Groups and Formations

- Groups
  - List of units
  - Max/avg speed
  - Centroid or leader
- Formation
  - Orientation (front)
  - Each unit has unique position and orientation



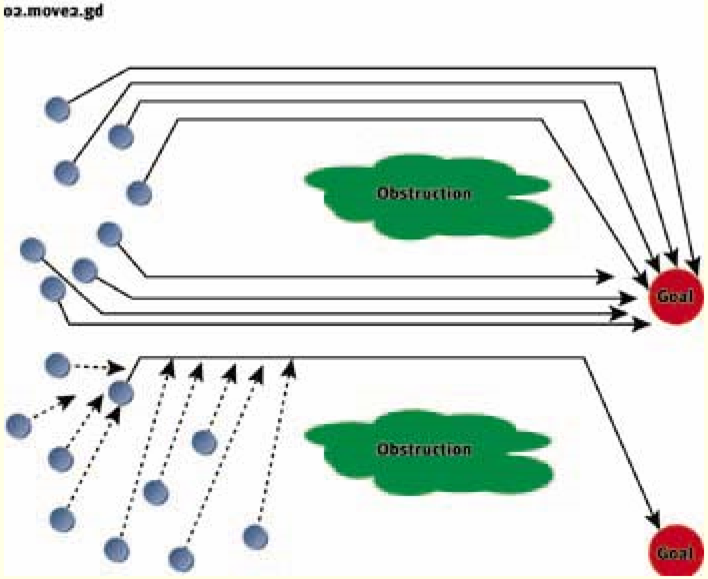
Group movement

- Units should move with similar speed and time



02.move1.gd
Base speed
Time speed addition
Same speed
S
F
Slow units
Fast units
Direction of movement
Allow these units to move faster to catch up to fast units
Once all units are close enough, all units move at the same speed.

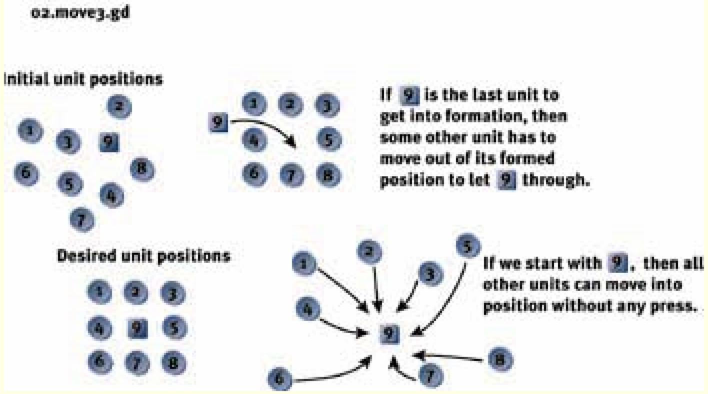
- Units should move in similar path (leader finds path, and others can follow that path)



Formation

- Ways to get into formation
  - Minimize distance travelled
  - Collisions
  - Travel time

- Tradeoff between computation time and realistic result

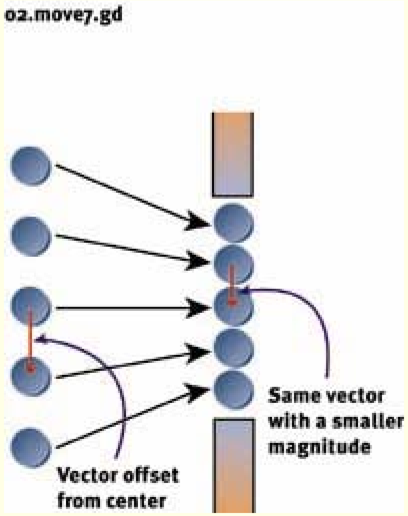


If 9 is the last unit to get into formation, then some other unit has to move out of its formed position to let 9 through.

If we start with 9, then all other units can move into position without any press.

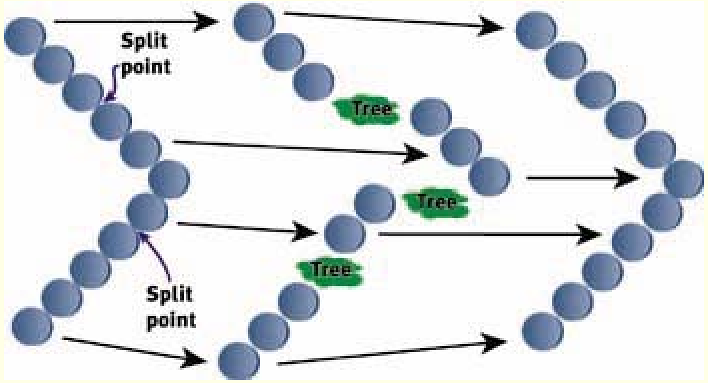
Formation Management

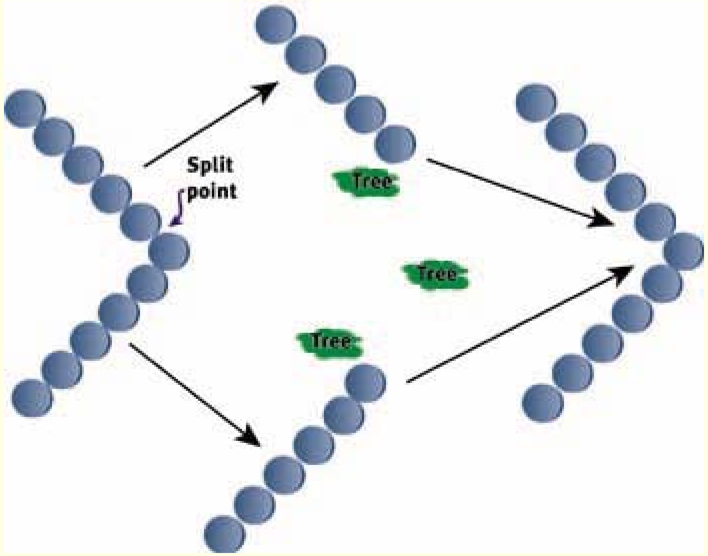
- Scaling positions


o2.move7.gd
Same vector with a smaller magnitude
Vector offset from center

Formation Management

- Splitting up and re-forming





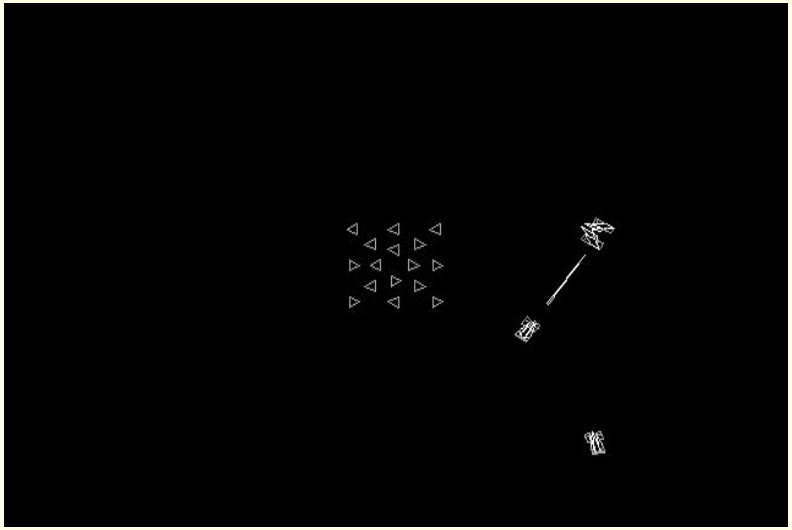
- When to regenerate path instead

Other examples – movies

- Many examples
  - Star Wars Episodes I and II, The Lion King, Mulan, Dinosaurs, 101 Dalmatians, Pearl Harbor, Galaxy Quest, The Mummy and The Mummy Returns, all three Harry Potter films, Antz, Shrek 2, Prince of Egypt, Starship Troopers, The One, How the Grinch Stole Christmas, I Robot, The Day After Tomorrow, Anger Management, Matrix: Reloaded, Matrix: Revolutions

Other examples – "Rip-Off"

- First game demonstrating flocking



Other examples – "Rip-Off"

- "arrival" – enemy go towards target and slow down
- "separation" – within radius of another rank, an enemy tank will steer away
- If within radius of player tank, shoot at player