Humanoid Crowd Behaviour

Slides from Chris Peters

Why ?

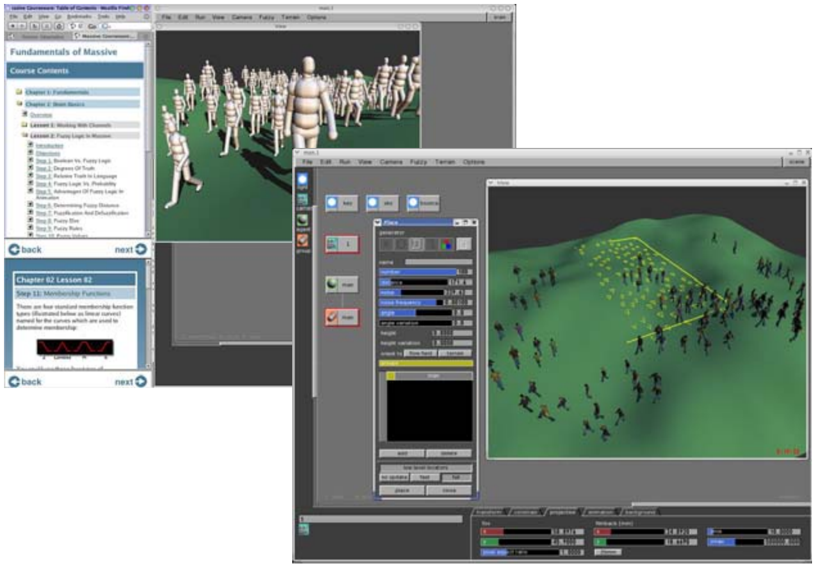
- Add realism to scenes that would otherwise look desolate
  - Many computer generated environments are like “Ghost towns”
  - Very few humans to be seen
  - Where is everybody ?

Applications

[Thalmann et al 2006]

- Populating virtual city models
- Architectural walkthroughs
- Fire evacuation simulations
- Here we will be considering only behaviour
  - Lots of other issues
  - Rendering, low-level animation

MASSIVE



MASSIVE, © *Weta Digital*

Lord of the Rings, © *New Line Cinema*

- Lord of the Rings
  - Real actors near to camera
  - Agents fill in those areas behind
  - Otherwise, very expensive to pay all those extras, costumes, etc !
- Vision sensors, motion captured clips, action selection
  - Semi-autonomous
  - Manual set-up important

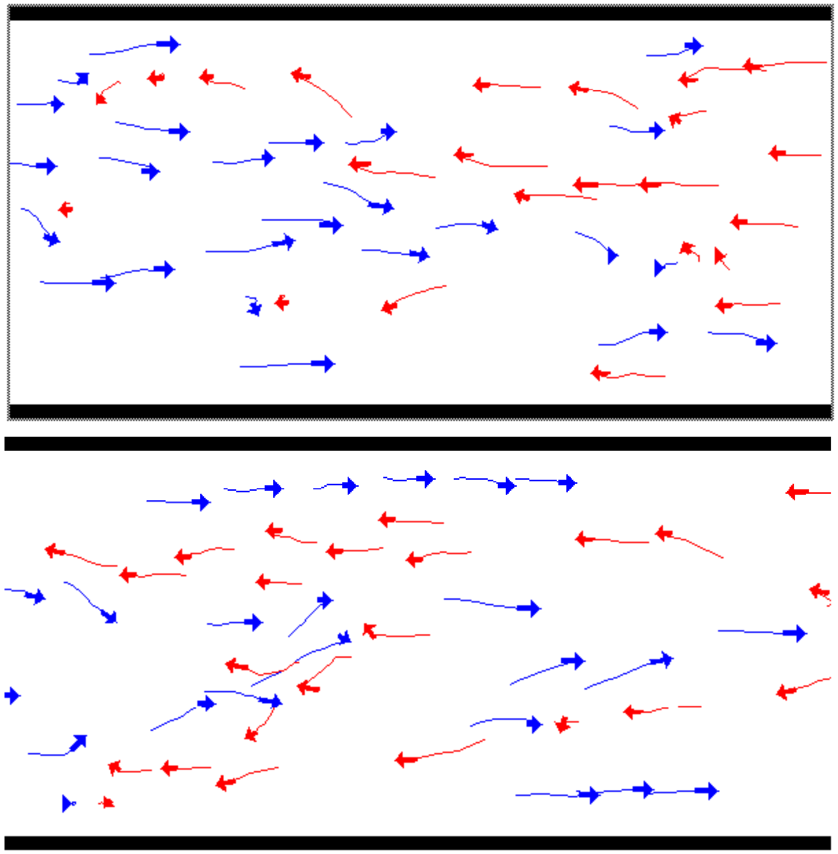
GTA: Vice City

Some Approaches

- General classification
  - Social-forces
    - E.g. Helbing and Molinar 1995
  - Cellular automata
  - Rule-based
    - E.g. Reynolds 1987, Shao and Terzopoulos 2005
- Environment
  - Cells and portals
  - Potential fields
  - Roadmaps
  - Other embedded information

Social Forces

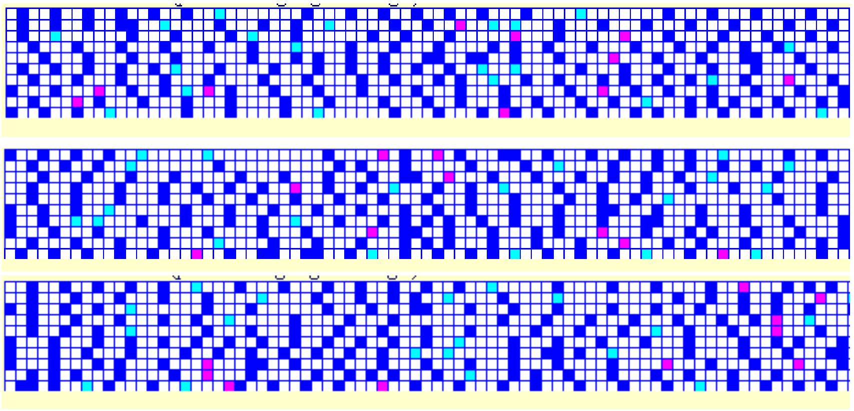
- Helbing social force model
  - Physical and socio-psychological factors
  - Particle system
  - Applies repulsion and tangential forces
  - Simulate
    - Interactions between people and obstacles
    - Realistic pushing behaviours, lane formation
    - Variable flow rates
  - Problems:
    - Tend to behave more like particles than humans
    - Agents vibrate in high-density crowds



http://rcswww.urz.tu-dresden.de/%7Ehelbing/Pedestrians/Corridor.html

Cellular Automata

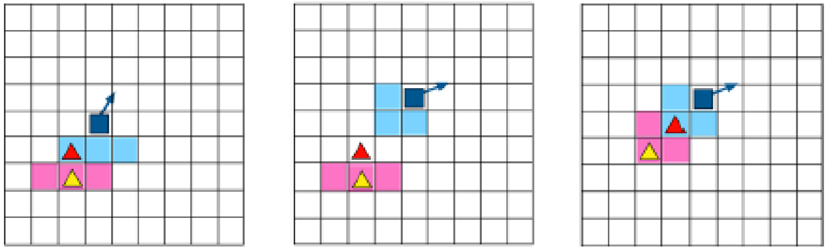
- Pedestrians simulated as particles in a grid of cells
  - Floor space is discretized
- Pedestrian picks the most beneficial neighbouring cell to proceed toward
  - Based on information stored in these local neighbouring cells



[Blue and Adler, 2000]

Cellular Automata

- Advantages
  - Tend to be fast calculations
  - Easy to implement
- Disadvantages
  - Do not allow for contact between agents
  - Individuals can only move when adjacent cell is free
  - Limit agent spatial movements
  - Expose underlying checkerboard of cells when density is high
- Higher-level behaviours can be incorporated
  - E.g. pre-defined paths towards high-level goals stored in grid



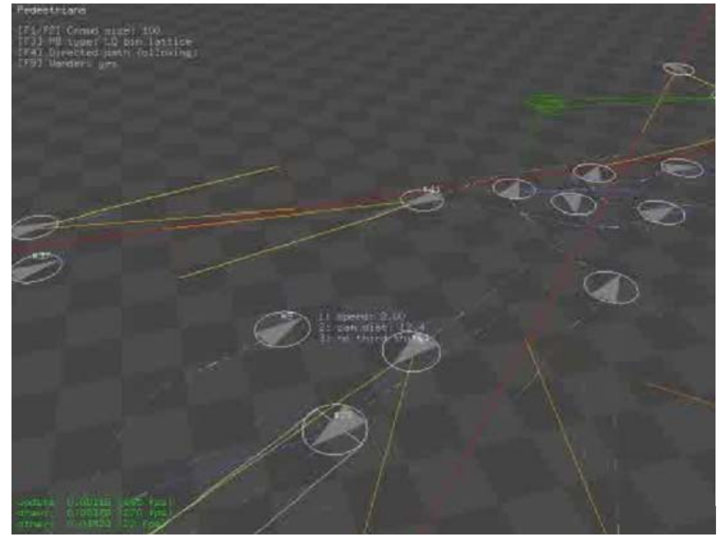
[Loscos et al, 2003]

Rule-based Models

- Reynolds
- Shao and Terzopoulos
  - Mixed with cognitive model
- Advantages:
  - Realistic results for low and medium density crowds
- But…
  - Tend not to consider collision detection and repulsion
    - Usually avoid contact and when densities are high
    - Apply waiting rules instead
    - No need to calculate collision detection and response
    - Fail to simulate pushing behaviour
  - Agents appear a bit too well behaved sometimes

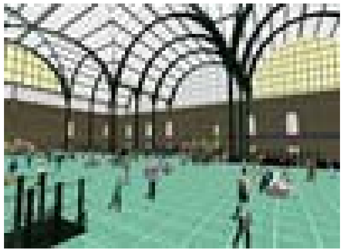
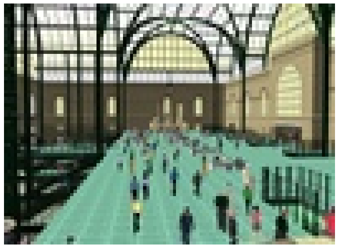
"Boids"

- Recall, three steering behaviours:
  - Separation
  - Cohesion
  - Alignment
- Great for fish etc
- Basic results not so good for humans
- But that doesn't mean *steering behaviours* can't be augmented
  - See the OpenSteer pedestrian plug-in



© Reynolds, 1999

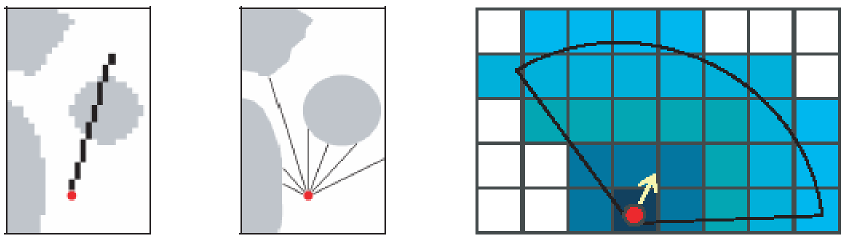
Autonomous Pedestrians

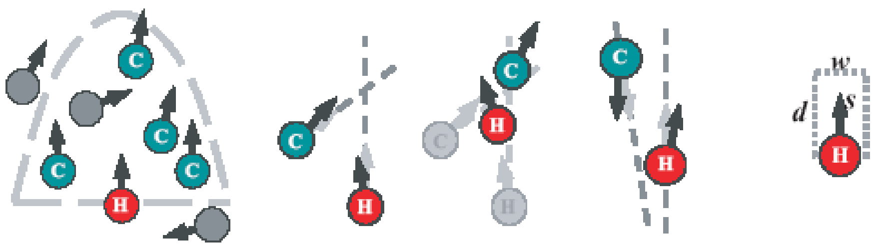




Shao and Terzopoulos 2005

- Shao and Terzopoulos
  - Model individuals
  - Cognitive modelling
  - Deliberative as well as reactive behaviours
  - Virtual environment represented by hierarchical collection of maps
    - Topological – high level links
    - Perception
    - Path – long range and short range path planning

Autonomous Pedestrians





Shao and Terzopoulos 2005

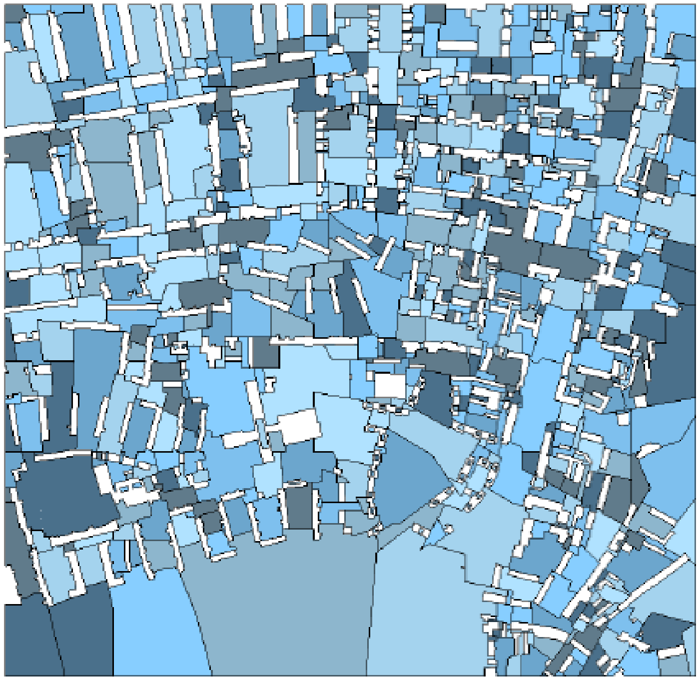
- Perception
  - Stationary *(left, middle)* and mobile objects *(right)*
- Behavioural control
  - Primitive reactive behaviours
  - Building blocks to support more complex behaviours
  - Controlled by action selection mechanism
- Cognitive control
  - Global path planning
  - Goal stack

Environment Representation

- Important for supporting crowd calculations
  - Spatial partitioning
    - Split up the world into zones
  - Potential fields
    - Add flow direction information into the world
  - Roadmaps
    - Add graph representation to help path-finding
  - Embedded information
    - Add other information, such as object semantics

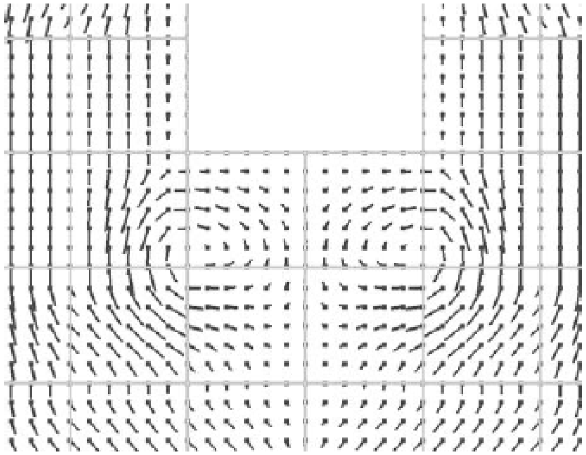
Spatial Partitioning

- Cells and Portals
- Automatically partition a city-like environment into zones
- Portals are connections between those zones
  - Think of them as windows that connect two zones together



[Lerner et al 2006]

Potential Fields

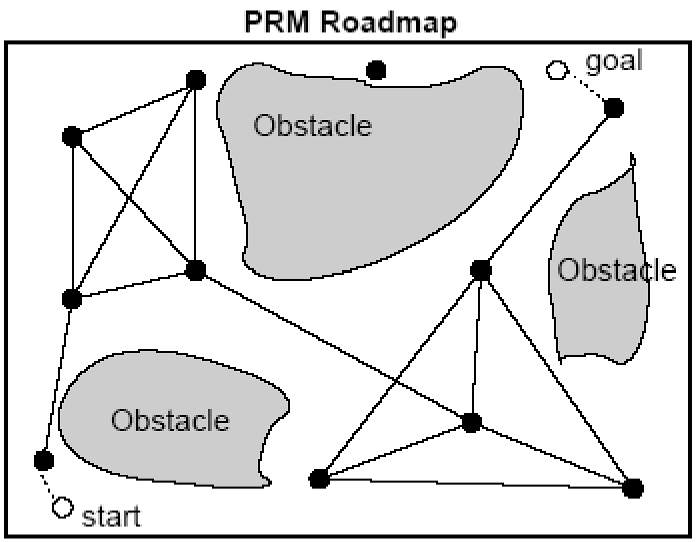


[Chenney 2004]

- Potential fields
  - Velocity fields
  - E.g. “Flow Tiles”
  - Each tile is a small stationary region of velocity field
  - Tiles can be pieced together to form larger velocity fields
  - Easy to design

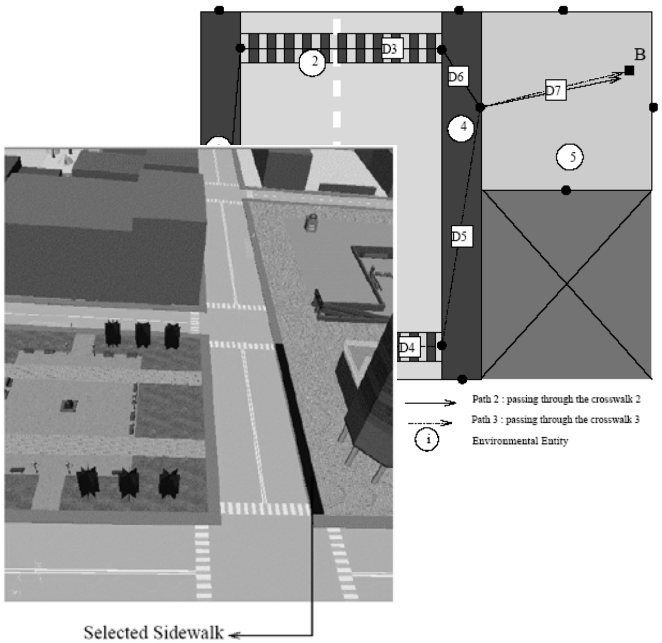
Roadmaps

- Network of feasible paths in environment
- Aids coordinated group navigation
- PRM: probabilistic road map
  - Sample points randomly
- Preprocessed
- Locate initial and final positions on map
  - Select route connecting them
- Homing
  - Move entire flock from start position to goal position
- Goal-searching
  - Individual members search scene for goal
  - Once found, all group members move to that location
- Shepherding
  - Steering by external agent



[Bayazit et al, 2002]

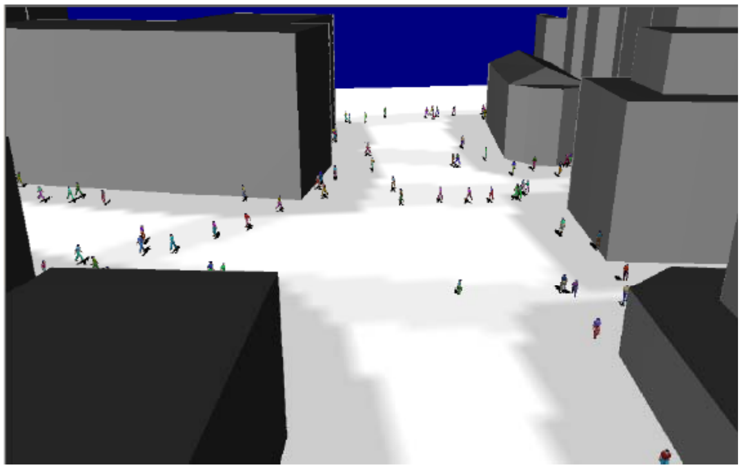
Other Embedded Info



[Farenc et al, 1999]

- Add semantic information
  - And associations between geometric and semantic information
  - Provide information necessary for recognition of places and locations of various objects
  - E.g. recognise a footpath
  - Environmental entities
    - Obstacles
  - Attached action information
  - Hierarchical decomposition of scene

Embedded Info



- Collision maps
  - Represent city by 2D array at a certain resolution
  - Binary map
    - Represents only buildings and ground
    - Pedestrians directly access this map by location
    - Find out where they can and can't walk
    - But not so realistic, since allows pedestrians to walk on roads
- So represent crossings and pavements too

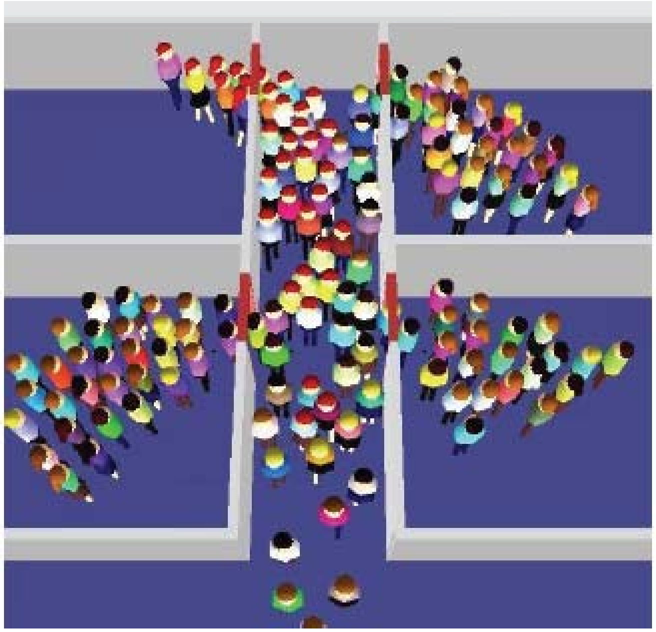
[Loscos et al, 2003]

HiDAC

- High Density crowd simulation
- Parameterised social forces model
- High-level module decides what waypoint an agent walks to within a room
- Agents react to static and dynamic objects and other agents within a nearby space
  - Over longer distances, tangential forces steer agents smoothly around obstacles
  - Over shorter distances, collision response is applied
- Politeness and panic
  - Agents in a hurry do not respect each others personal space and appear to push their way through the crowd
  - Polite agents respect queuing and wait for others to move first

HiDAC

- Factors influencing agent behaviour
  - Geometrical information and psychological rules mixed with forces model
  - Psychological
    - Agents have different psychological traits
      - Impatience
      - Panic
      - Personality
  - Physiological
    - Agents have different physiological traits
      - Locomotion
      - Energy level
  - Geometric rules
    - Distance
    - Areas of influence
    - Relative angles



[Pelechano and Balder 2007]

HiDAC

- Agents in a hurry do not respect each others personal space and appear to push their way through the crowd
- Polite agents respect queuing and wait for others to move first
- No centralised controller
  - Personality variables
  - High-level behaviours: navigation, learning, communication, decision-making
  - Low-level motion: perception, reactive behaviours
- Agents have perceptive capability
  - Influence disk in front of agent that triggers waiting behaviour
  - Relaxed agents temporarily stop when another agent moves into their path
  - Impatient agents do not respond to this feedback and tend to push

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  - See http://isg.cs.tcd.ie/cosulliv/Pubs/EG2006course.pdf