Interactive Simulation of Plausible Crowd Behaviors

UNC DEPARTMENT OF COMPUTER SCIENCE

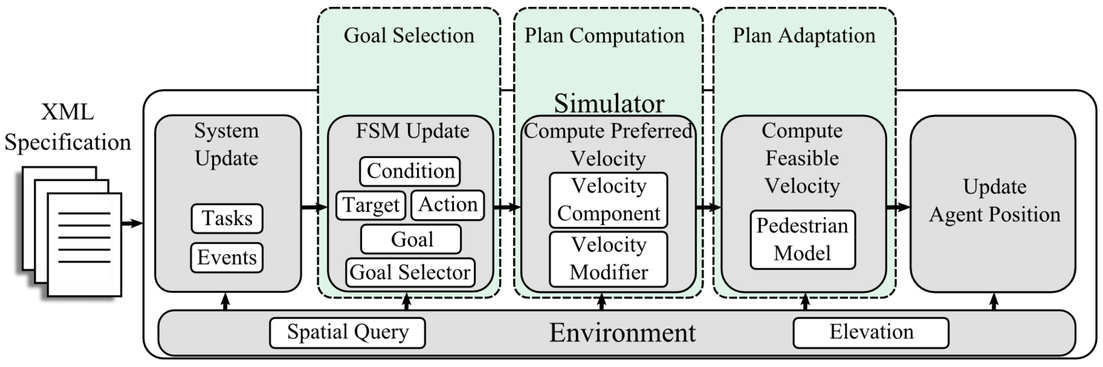
Sahil Narang, Andrew Best, Ming C. Lin and Dinesh Manocha

CV²R Consortium for Vision and Virtual Reality

http://gamma.cs.unc.edu/research/crowds/

Menge Framework

- Modular crowd simulation framework developed at UNC.
- Decomposes crowd simulation into discrete elements which can be mixed together, or extended via plugins to create novel simulators.
- Can simulate diverse and complex behaviors and populations through its extensible Behavioral Finite State Machine (BFSM).

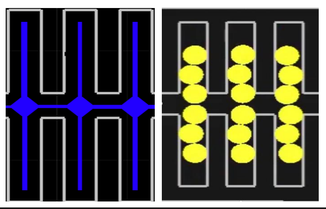


The Elements of the Menge framework in the simulation pipeline. For more information, see [Curtis 14].

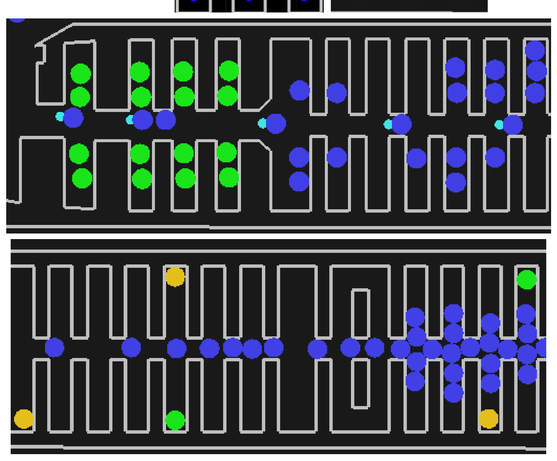
Pedestrian Simulation of Aircraft

- A pedestrian simulation system to model loading, unloading, and evacuation of commercial aircraft.
- Addresses the challenge of simulating passenger movement in constrained spaces (e.g., aisles and rows).
- Models different categories of passengers and flight crew, capturing their unique behaviors and complex interactions.
- Simulated movements on Boeing 737, and Boeing 777.

Experiments



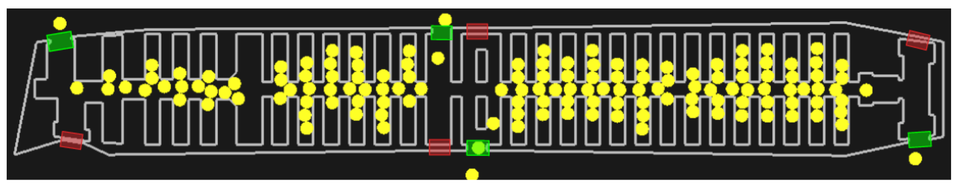
Global Navigation
Sampling based methods may cause deadlocks, and potentially fail to find a solution because of minimal clearance.



Aircraft Boarding
Boarding agents enter the aircraft, stow luggage, and find their seats.
Seated agents may yield to incoming agents through coordinated interactions

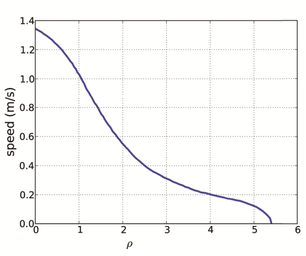
Aircraft Deplaning
Typical agents leave their seat, collect their luggage and exit. Once the aisles are clear, flight attendants assist infirm agents out of the aircraft.

Aircraft Evacuation: We can simulate different evacuation scenarios by obstructing the exits (red). Agents experience stress over time, generating impulsive and careless behaviors.

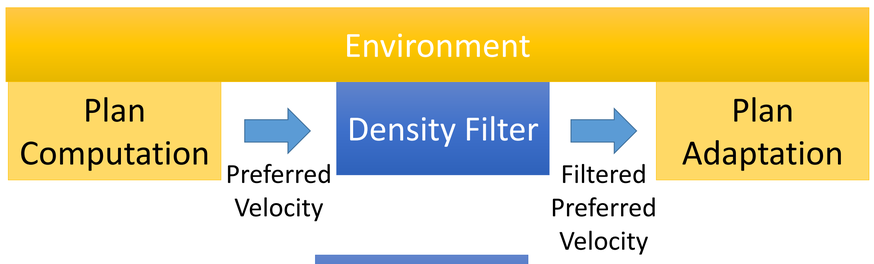


Density-Dependent Behaviors

- A novel method to generate pedestrian trajectories in dense scenarios that exhibit the Fundamental Diagram.
- The Fundamental Diagram is the observed relationship between pedestrian speed and density; as density increases, speed decreases.
- We propose a **density filter** which modifies the preferred velocity w.r.t. local density conditions.



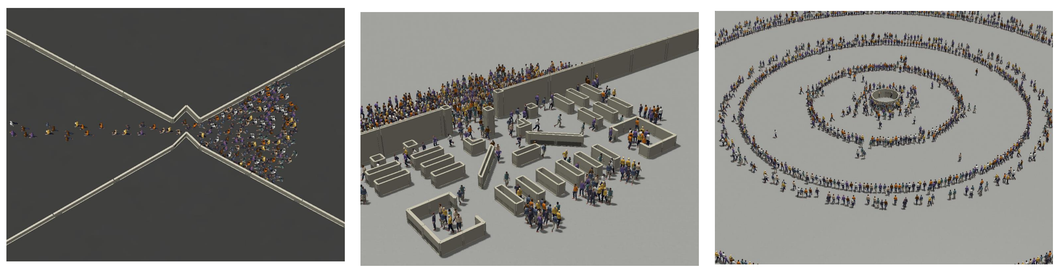
Density Filter



- Biomechanical principle that relates stride length and walking speed.
- Humans have a strong sense of personal space that extends beyond physical requirements.

Collaborators: Sean Curtis & David Kasik, The Boeing Company.

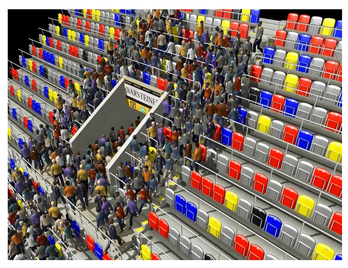
Example Scenarios



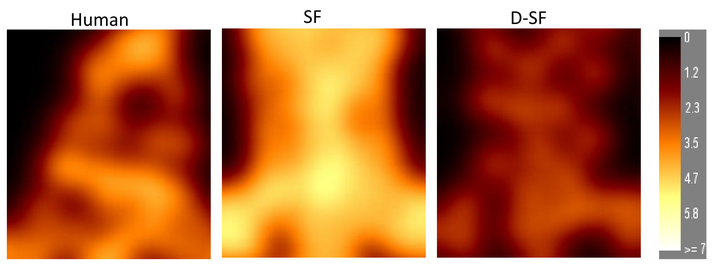
Hourglass (Left): 200 agents rush through a narrow passage with concave windings.
Mall (Center): 1000 rush inside a shopping mall.
Kiosk (Right): 1900 agents move in concentric circles towards a kiosk in the center. They are programmed to wait for 10 seconds before heading outward again.

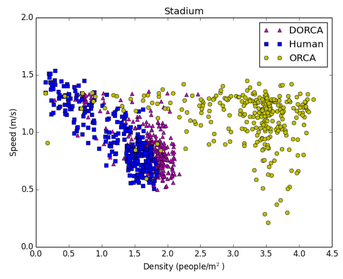
Validation

Fundamental Diagram
Comparison of simulated agents with density filter (D-ORCA), naïve algorithm (ORCA) and real world data for Stadium Exodus.



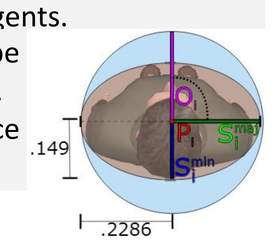
Density Heat Maps
Comparison of simulated agents with density filter (DSF), naïve algorithm (SF) and real world data for Stadium Exodus.





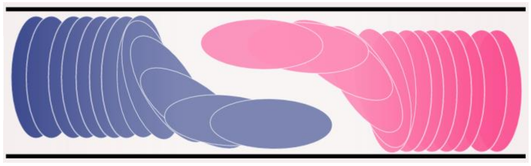
Human-like Collision Avoidance

- A practical approach for interactive crowd simulation using elliptical agents.
- The elliptical approximation (brown) captures the pedestrian shape more accurately, compared to typical disc-based approximation (blue).
- Conservative piecewise linear approximation with collision avoidance guarantees.



Orientation Update

- Our method links orientation computation to velocity, reducing the dimensionality of motion planning.
- Capable of simulating side-stepping, shoulder-turning, and backpedaling in dense crowds.



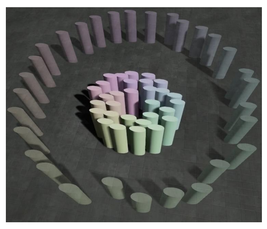
Two ellipses pass each other in a narrow hallway by shoulder turning and sidestepping.

Validation

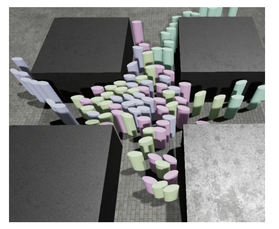
- Comparison with observed pedestrian avoidance behaviors in crossing flows.
- Comparison of simulated agents with real world data for bidirectional flow.

(Left) Simulated crossing flow. (Center) Captured frame for bidirectional flow. (Right) Simulated bidirectional flow

Example Scenarios

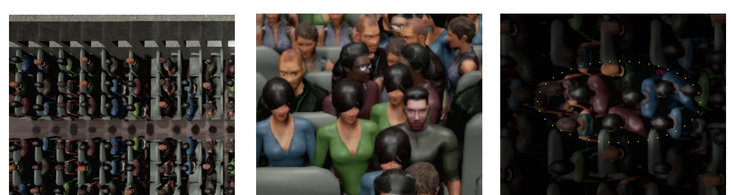


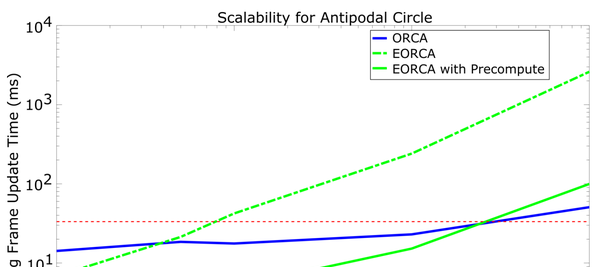
Antipodal Circle
100 agents initialized in a circle with goals set to the antipodal position.



Four-Square
Four groups of agents cross through a constrained space between four large obstacles.

Aircraft Deplaning
157 agents exit a commercial aircraft. The agents stand up, side-step through the narrow seat passage to the aisle, fetch their luggage and exit the aircraft.





Scalability

Simulation using elliptical agents (EORCA) is 4-5x slower than disc-based agents (ORCA) but still interactive for 1000's of agents for the antipodal circle. The dotted red line denotes 30 FPS.

Sponsors: NSF, Office of Naval Research, BOEING