Position-based Torso Crowds

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Problem

- Crowd simulation methods represent crowd agents as discs [1].
- Discs are a conservative approximation of a person's top-down profile [2].
- Discs do not accurately capture pedestrian dynamics in several scenarios [3].
- Capsules better approximate the profile of the human body (see figure on right).

Related Work

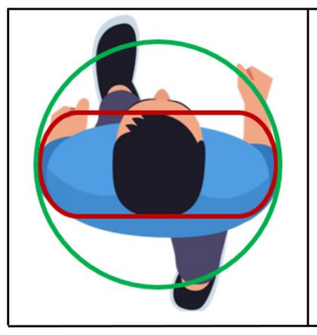
- Many crowd simulation methods rely on disc-shaped agents [1].
  - ✓ Computing agent interactions, and collision avoidance maneuvers is straightforward.
  - ✓ Discs cannot capture rotation, which influences crowd navigation behaviors [2].
- Stüvel and colleagues [3] used a capsule representation for simulating dense crowds, focusing on body rotations based on available clearance.
  - ✓ Work in strict settings where crowd is divided to active and passive passive agents, in high-density scenarios.
  - ✓ Uses a generalized Voronoi diagram for agent navigation.
- Best et al. [4] represented crowds as elliptical shapes.
  - ✓ While ellipses are better than discs in terms of capturing the torso profile, ellipses are more conservative than capsules.

Our Approach

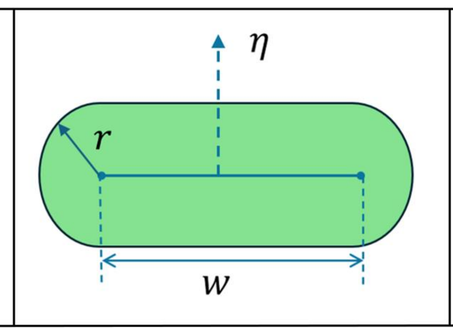
- We simulate crowds using position-based dynamics (PBD).
- Simulating crowds using PBD allows interactive simulation for a large number of agents.
- We develop constraints for capsule-shaped PBD particles.

Contributions

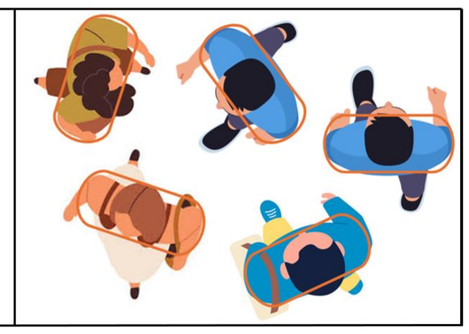
- We propose new position-based dynamics (PBD) constraints for capsule crowd navigation.
- **Long-range collision avoidance constraint** for capsule-shaped agents.
- **Rotation constraint** that allows the capsule to change their orientation smoothly.



Spheres overestimate the ground projection of a human torso



We represent crowds as capsules.

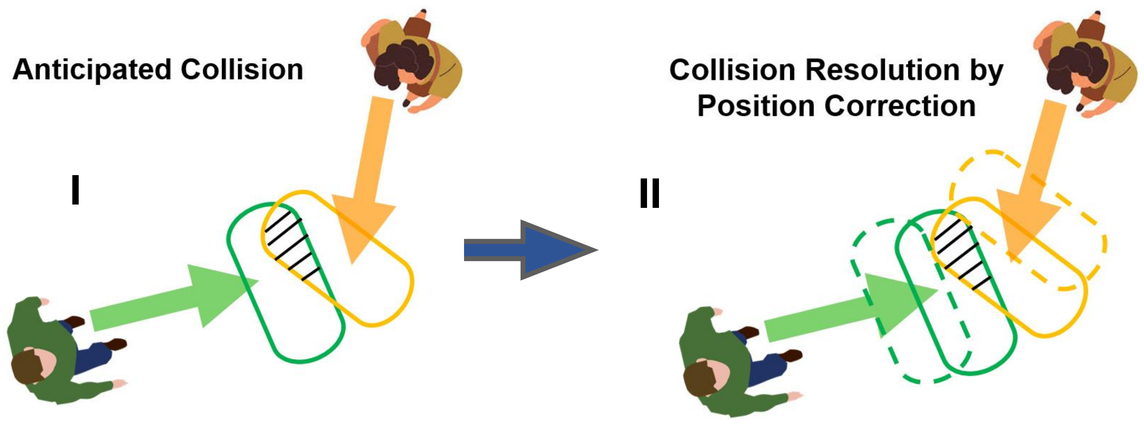


Capsule approximate human torsos more accurately than spheres

Abstract

- We propose a novel crowd simulation method that represents crowd agents as 2D capsules rather than traditional discs
- While discs are commonly used due to their simplicity, a disc does not accurately capture profile and orientation of crowd agents, and therefore misses intrinsic dynamic details of crowds in various settings. Leveraging position-based dynamics (PBD), we simulate crowds of capsule-shaped agents in multiple settings.
- We propose innovative constraints for multi-agent navigation with capsules, enhancing the fidelity and applicability of crowd simulations in diverse environments and scenarios.

Long-range Collision Constraint



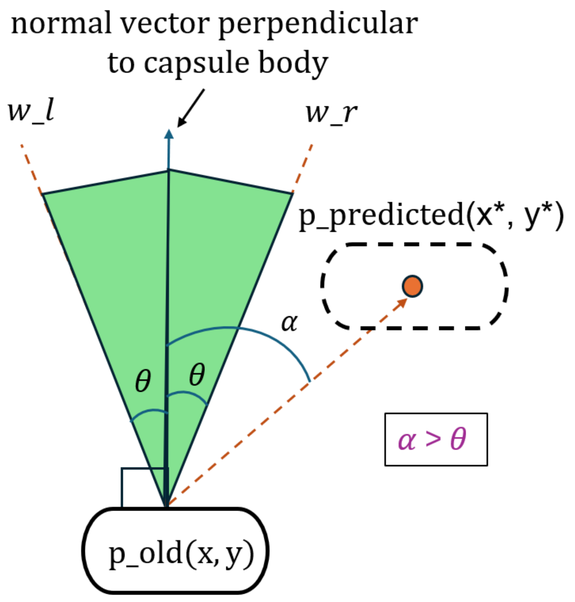
The closer the collision is (time-wise)

The stronger the avoidance behavior

Rotation Constraint

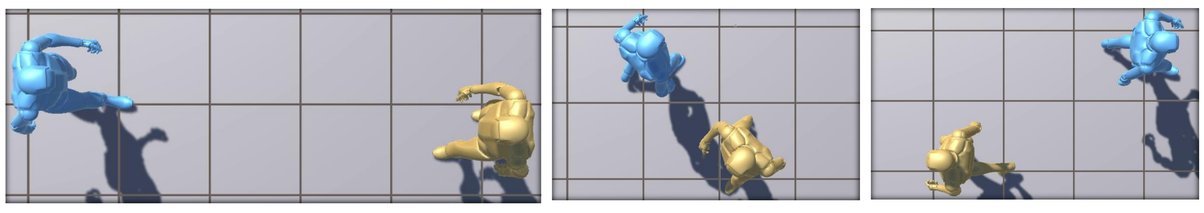
To limit agents from rotating unrealistically during a time step, we:

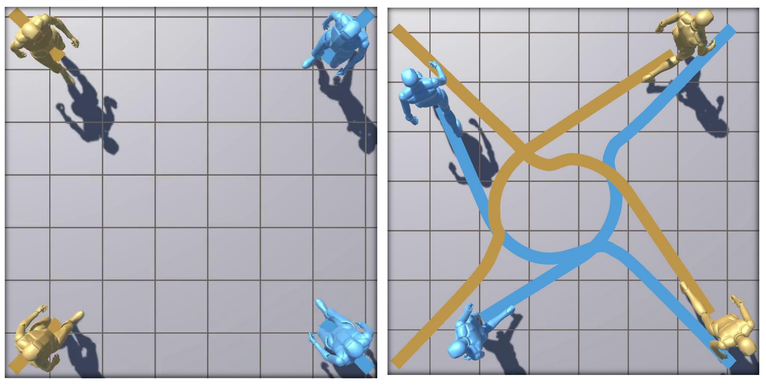
- We calculate two direction vectors w_r and w_l ,θ degree deviated in the right and left side of the capsule body normal respectively.
- Calculate the agent's predicted position $p_{predicted}$
- If this point is above the threshold θ degree with respect to capsule body normal, we activate the constraint.



The constraint projects the predicted position $p_{predicted}$ on the above cone, and projects $p_{predicted}$ to the nearest point on w_r and w_l.

Results





Two agents passing each other (Top): Capsules rotating their body with anticipatory movement to avoid each other in a hallway heads-on scenario using our method.

Four Agents Crossing (Left): Capsules are positioned to the corners of a rectangle and are tasked to reach their opposite diagonal corner. Capsules reached their goals successfully maintaining smooth trajectories.

Position-based Dynamics

- Simple, stable, and scalable for physics-based simulations.
- Agent positions are iteratively updated with geometric constraints.
- Constraints C control agent dynamics:.
  - ✓ Scalar functions are either equality $C()$=0, or inequality $C()$ ≥ 0

Long-range Collision Constraint

- Ensures agents maintain a safe distance from their neighboring agents to avoid collisions.
- First, PBD calculates capsule's positions in next timestep.
- Second, two potential contact positions for two capsules are calculated indicating the points at which capsules are likely to collide in future if they continue along their current trajectories.
- Third, time-to-collision (ttc_{ij}) that indicates when two capsules i and j will touch each other in the future is calculated using capsule's predicted positions, and their potential contact positions.
- Finally, positions are updated using (ttc_{ij}) to resolve potential collision.

Rotation Constraint

- Rotations are important in capturing navigation behaviors.
- During a time step, agent's predicted positions may deviate from the existing deviations, causing orientation changes.
- To avoid unrealistic maneuvers, we constrain orientation changes in to be within a threshold value.

Discussion

- We simulate crowds in common benchmark scenarios, capturing anticipatory navigation behaviors.
- We observed natural crowd navigation behaviors, performing collision avoidance maneuvers and orientation changes as necessary.

References

[1] W. Van Toll et al. "Generalized microscropic crowd simulation using costs in velocity space." Symposium on Interactive 3D Graphics and Games, 2020.
[2] L. Hoyet et al. "Perceptual effect of shoulder motions on crowd animations." ACM Transactions on Graphics, 2016.
[3] S. Stüvel et al. "Torso crowds." IEEE Transactions on Visualization and Computer Graphics, 2016.
[4] A. Best et al., "Real-time reciprocal collision avoidance with elliptical agents." IEEE International Conference on Robotics and Automation, 2016.