

Problem

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

Related Work

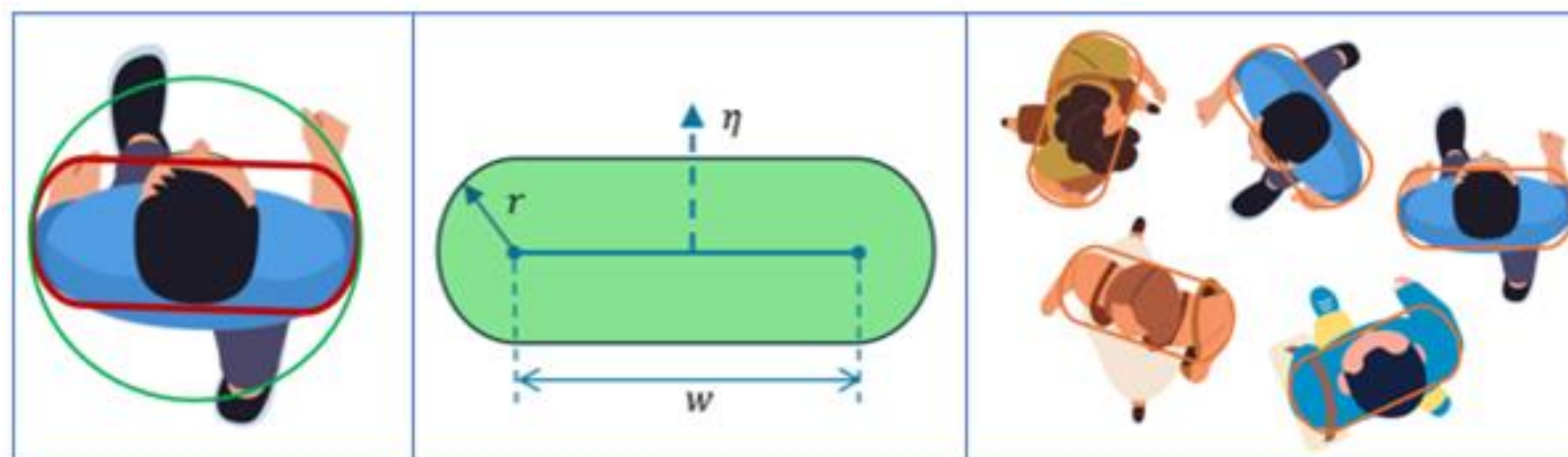
- Many crowd simulation methods rely on disc-shaped agents [1].
 - ✓ Computing agent interactions, and collision avoidance maneuvers is straightforward.
 - ✓ Discs do not readily encode rotation information, which influences crowd navigation behaviors [2].
- Stüvel and colleagues [3] used a capsule representation for simulating dense crowds, focusing on body rotations based on available clearance.
 - ✓ Does not consider entire crowd movements, but rather active versus passive agents.
 - ✓ Scope is limited to high-density scenarios.
 - ✓ Uses a generalized Voronoi diagram which is used to find a agent positions..
- Best et al. [4] represented crowds as elliptical shapes .
 - ✓ While better than discs, ellipses are more conservative than capsules.

Our Approach

- We simulate crowds using position-based dynamics (PBD).
- Simulating crowds using PBD allows interactive simulation for 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.



Speres overestimates the shape of the human torso

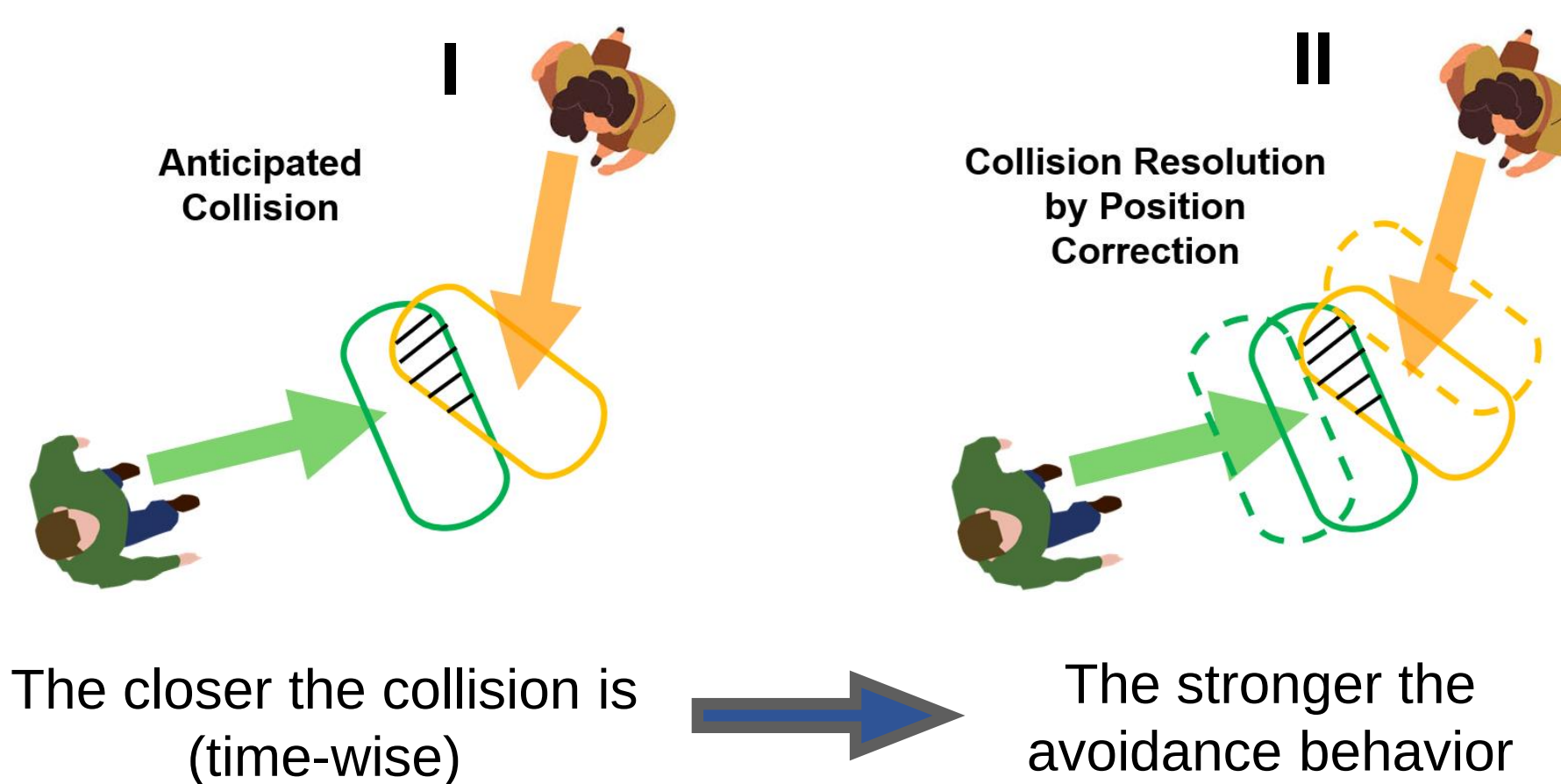
We represent crowds as capsules. η is the normal vector to capsule body.

Capsule shapes can approximate the human torso more accurately than speres

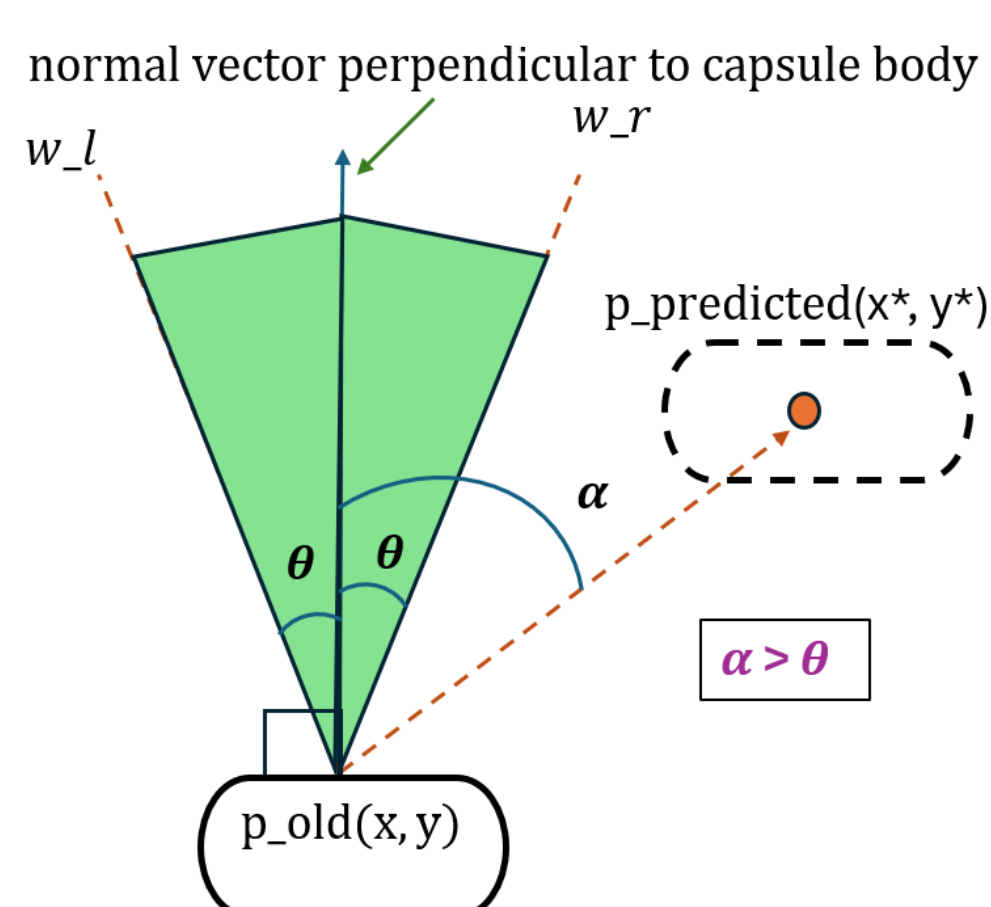
Abstract

We propose a novel crowd simulation method that represents crowd agents as 2D capsules rather than traditional discs, offering a more accurate approximation of human body profiles. While discs are commonly used due to their simplicity, a disc overestimates the actual 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 capsule-shaped agents in multiple settings. e 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

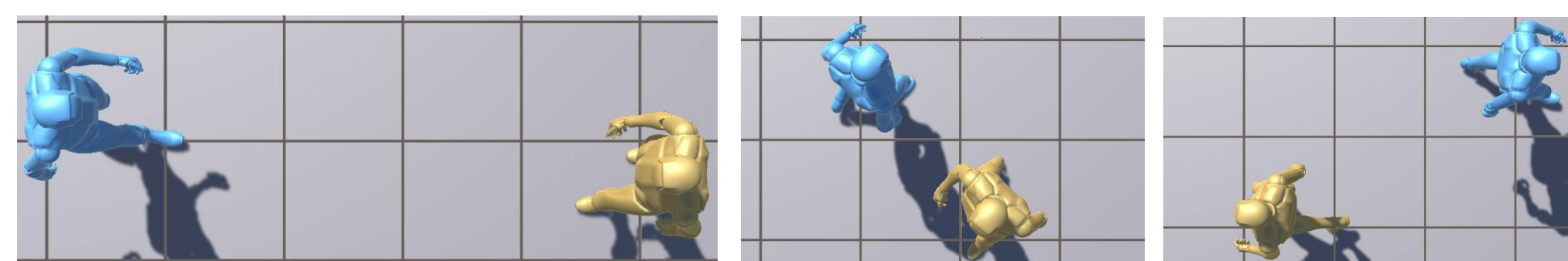


Rotation Constraint

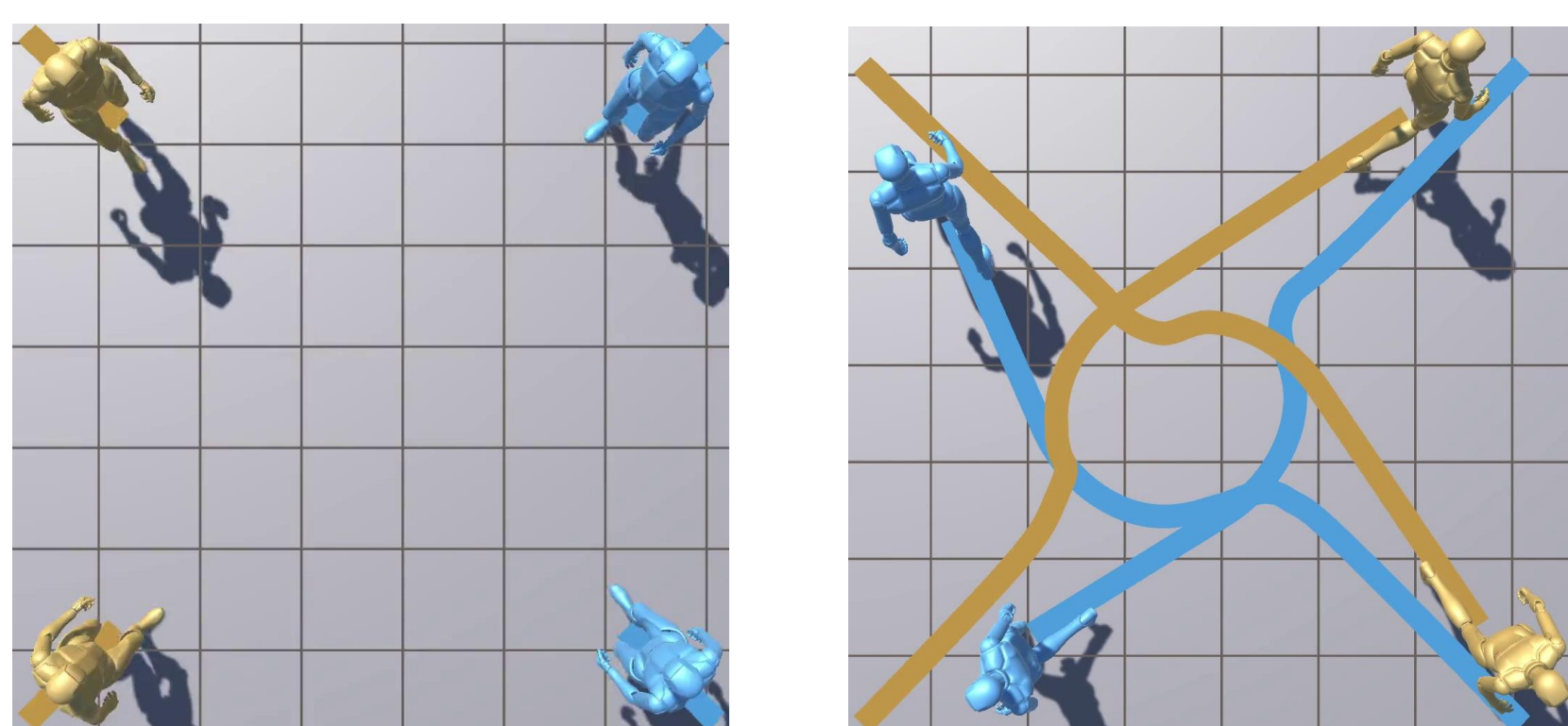


Rotation Constraint: In case of agent's predicted position $p_{predicted}$ in the next timestep calculated by PBD is above the threshold θ degree with respect to capsule body normal, we calculate two direction vectors w_r and w_l , θ degree deviated in the right and left side of the capsule body normal respectively. Then we find two new points projecting predicted position $p_{predicted}$ in w_r and w_l directions respectively, and select the point that is closer to $p_{predicted}$ as the corrected predicted point in the next timestep.

Results



Capsules rotating their body with anticipatory movement to avoid each other in a hallway heads-on scenario using our method.



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 using out method.

Position-based Dynamics

- Positions are iteratively updated based on constraints to achieve a desired behavior.
- Simple and stable.
- PBD uses constraints C to control agent behavior.
 - ✓ Scalar functions are either equality $C()=0$, or inequality $C() \geq 0$

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}) so that potential collision is resolved

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 simulated crowds in common benchmark scenario, 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 microscopic 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