Analyzing the Accuracy of Agent Representations in Crowd Simulations

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Introduction

- A crowd simulation models virtual humans (agents) in order to realistically emulate the behavior of real humans.
- They are used in many different domains from movies to emergency evacuation scenarios (Sagun eta al., 2008; Pelechano & Malkawi, 2007).
- For example, in emergency evacuation scenarios they attempt to predict the movements of a real crowd if an emergency were to occur (Sagun, 2008).
- Typically, simulations use disks to represent the area of exclusion of an agent.
- The two most common disk representations include:
  - *Minimum Disk Representation:* A disk that has a diameter close to an average agent's shoulder width (50 cm) (van Toll et al., 2021; Wolinski et al., 2016).
  - *Maximum Disk Representation:* A disk that has a diameter approximately equal to the maximum stride length of the agent (100 cm) (Wolinski, 2016; Weiss et al., 2017).

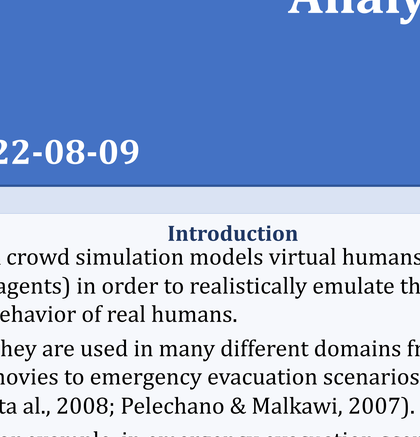

Figure 1: Comparison of Disk Representations

Figure 2: Agent-Agent Mesh Overlap (Min Disk Representation)

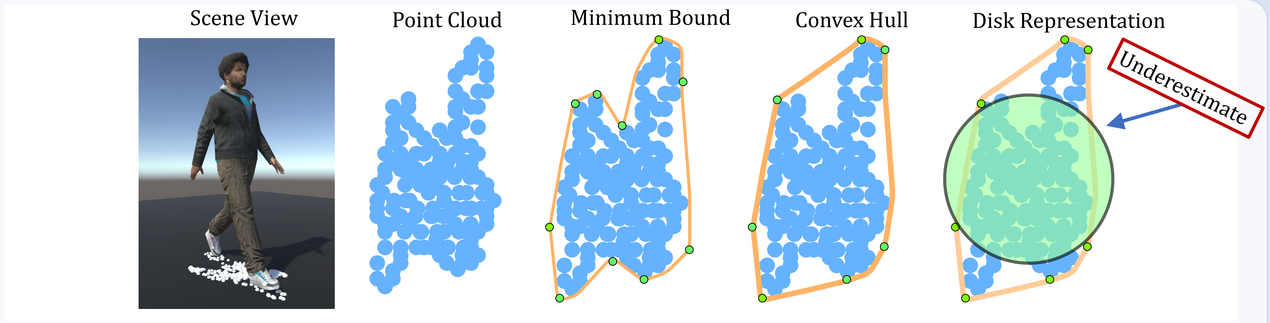

Figure 3: Illustration of the Space Coverage of A Character's Mesh by Projecting the Mesh Vertices Onto the Ground Plane to Create the Convex Hull.

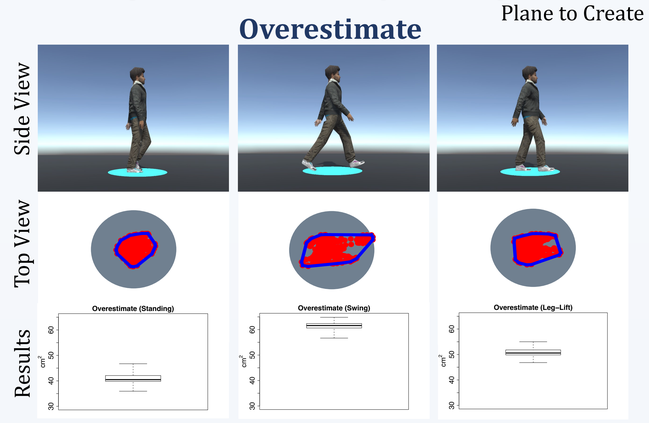

Figure 4: Cm^2 Difference in Area Between Convex Hull About Mesh Vertices and Max Disk Representation

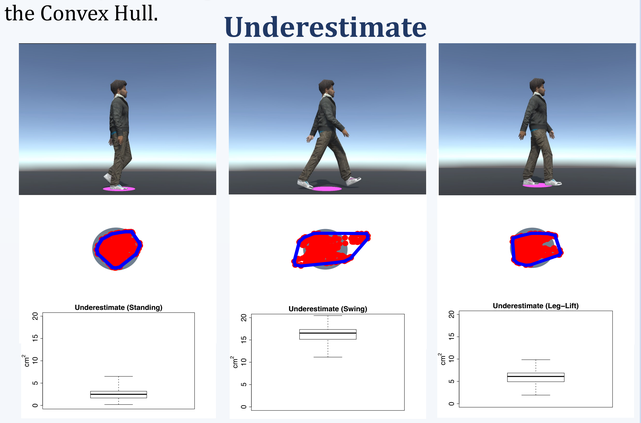

Figure 5: Cm^2 Difference in Area Between Convex Hull About Mesh Vertices and Max Disk Representation

Walk Cycle Phase

Animation Type	Standing (cm^2)	Swing (cm^2)	Leg-Lift (cm^2)	Disk Radius (cm)
Slow Walk	59.002	51.871	56.492	50
Walk	61.328	40.986	50.883	50
Run	49.227	31.739	44.652	50

Table 1: Cm^2 Difference in Area Between Convex Hull and Max Disk Representation Across Walk Cycles

Walk Cycle Phase

Animation Type	Standing (cm^2)	Swing (cm^2)	Leg-Lift (cm^2)	Disk Radius (cm)
Slow Walk	0.865	7.211	4.986	25
Walk	16.102	16.102	5.831	25
Run	9.915	25.182	14.298	25

Table 2: Cm^2 Difference in Area Between Convex Hull and Min Disk Representation Across Walk Cycles

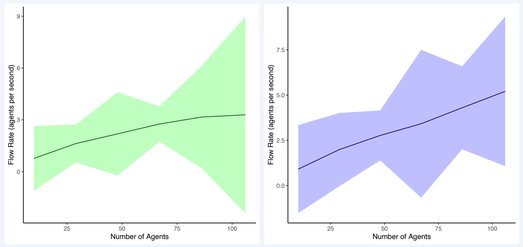

Figure 6: Flow Rate with *Left:* Max and *Right:* Min Disk Representations

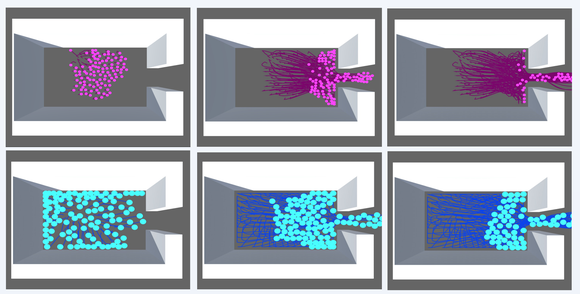

Figure 7: Flow Rate Test Scenario (*Top:* Min vs. *Bottom:* Max Disk)

Materials & Methods

- Analysis was performed on 115 unique characters from the Microsoft Rocketbox Avatar Library (Gonzalez-Franco et al., 2020).
- In order to measure the over- and underestimates, the mesh points making up the agent were projected onto the ground plane (Fig. 3).
- Over- and underestimates were measured by taking the difference between the area of the disc and the area of the convex hull (Fig. 4 and 5).
- Three unique animations including, a slow walk, neutral walk and a run, were analyzed.

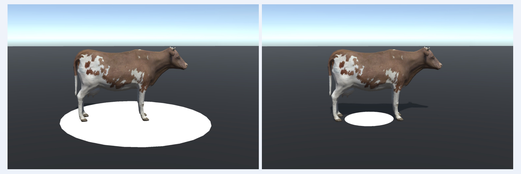

Figure 8: Error Compounds with Non-Standard Meshes

Results

- As summarized in Table 2 the greatest underestimate of $25.182cm^2$ was found during the swing phase of the run animation with a disk radius of 25cm.
- The greatest overestimate of $61.328cm^2$ was found during the standing phase of the walk animation with a disk of radius 50cm (Table 1).
- The agents with a smaller radius had a higher rate of flow (Fig. 6)

Conclusion & Discussion

- The results confirmed the hypothesis, that disks oversimplify the space that an agent occupies at any given time-step.
- Oversimplification has drawbacks which can affect the results of a realistic simulation resulting in negative consequences.
  - For example, in the flow rate analysis, it was shown that disks with a smaller radius have a faster rate of flow which is not reflective of the time it would take for humans to evacuate a building.
- In order to have better representations within simulations, agents should have a tightly bound area of exclusion, preventing them from overlapping with other agents while also allowing for tight packing (Fig. 2).
- While convex hulls present a good representation of the agent, they are costly to compute for each time-step. This prevents the simulation from scaling well.
- Future work includes analyzing other representations of agents in motion including deformable shapes and more efficient convex hulls.

Acknowledgements

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