Analyzing Human–Building Interactions in Virtual Environments Using Crowd Simulations

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1 Extended Abstract

There has been a growing focus on digitalizing the environment design process and opting for new means to explore these designs (e.g., via 3D walkthroughs and VR) [Usman *et al.*, 2017a; Usman *et al.*, 2017b] before they are actually built and used. It is also of great importance to account for human occupancies and their behaviours in the design and management of the environments to evaluate how the design would impact the activities and movement patterns of the prospective inhabitants. While there are many established performance evaluation tools for buildings and environments, they are mostly limited to evaluating energy, lighting, structure and cost. The evaluation of design efficiency in terms of occupant movements, space utilization, and its spatiotemporal impact on the user experience is typically left of designers' own intuition and experience. This results in producing design artifacts that may lead to severe consequences in terms of safety, productivity and user-experience for their potential occupants.

Predicting human movements and behaviours in environments can be quite challenging even for experts, considering their size, functionality, and occupancy. Computational workflows are thus needed to evaluate designs for human occupancies and analyze the implications of design decisions on occupant movements and behaviours, from the beginning of the design process and not just at the very end. To this end, a dynamic workflow using crowd simulations [Kapadia *et al.*, 2015; Pelechano *et al.*, 2008] is proposed to simulate and analyze human–building interactions in semantically meaningful environments. Crowd simulations provide a time-based representation of the environment in-use by its prospective occupants. The dynamic workflow enables users to model the environment, define occupancies, their behaviours, and the activities they engage in. The analyses from these human–building simulations provide an intuitive way to identify problem areas, improve environment designs, and compare design alternatives concerning occupant related factors by insights from spatial quantitative and qualitative feedback and visualizations.

Partially, the focus of this work has been to provide these dynamic solutions [Usman *et al.*, 2020; Schaumann *et al.*, 2019; Usman *et al.*, 2018; Usman *et al.*, 2019a; Usman *et al.*, 2019b] to the end-users directly into mainstream environment modeling platforms (e.g., Autodesk Revit). This is to enable designers to design environments that are more human-aware by simulating dynamic crowds into these designs from within the CAD pipelines. Users can investigate the analytics (Figure 1) for human-building interactions in real-time in the form of path/trajectory analyses, bottleneck analyses, time and distance-based crowd traces, and density and speed heat maps of occupant movements, and can make more informed design decisions.

References

[Kapadia *et al.*, 2015] Mubbasir Kapadia, Nuria Pelechano, Jan Allbeck, and Norm Badler. Virtual crowds: Steps toward behavioral realism. *Synthesis lectures on visual computing: computer graphics, animation, computational photography, and imaging*, 7(4):1–270, 2015.

[Pelechano *et al.*, 2008] Nuria Pelechano, Jan M Allbeck, and Norman I Badler. Virtual crowds: Methods, simulation, and control. *Synthesis lectures on computer graphics and animation*, 3(1):1–176, 2008.

[Schaumann *et al.*, 2019] Davide Schaumann, Seonghyeon Moon, Muhammad Usman, Rhys Goldstein, Simon Breslav, Azam Khan, Petros Faloutsos, and Mubbasir Kapadia. Join: an integrated platform for joint simulation of occupant-building interactions. *Architectural Science Review*, pages 1–12, 2019.

[Usman *et al.*, 2017a] Muhammad Usman, Brandon Haworth, Glen Berseth, Mubbasir Kapadia, and Petros Faloutsos. Perceptual evaluation of space in virtual environments. In *MIG*, pages 16:1–16:10. ACM, 2017.

[Usman *et al.*, 2017b] Muhammad Usman, Brandon Haworth, Glen Berseth, Mubbasir Kapadia, and Petros Faloutsos. Understanding spatial perception and visual modes in the review of architectural designs. In *Proceedings of the ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, pages 1–2, 2017.

[Usman *et al.*, 2018] Muhammad Usman, Davide Schaumann, Brandon Haworth, Glen Berseth, Mubbasir Kapadia, and Petros Faloutsos. Interactive spatial analytics for human-aware building design. In *Proceedings of MIG*, page 13. ACM, 2018.

[Usman *et al.*, 2019a] Muhammad Usman, Davide Schaumann, Brandon Haworth, Mubbasir Kapadia, and Pet-

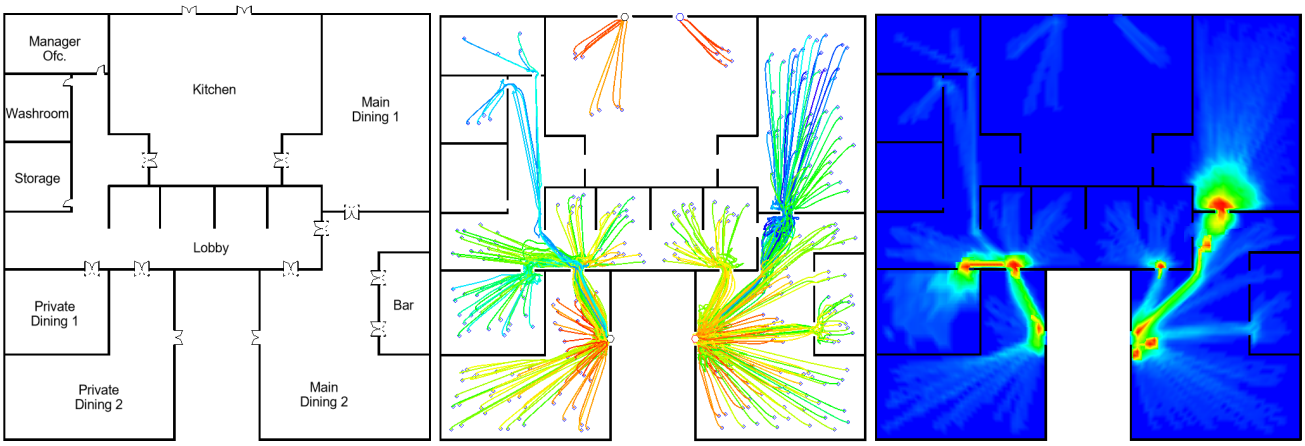

Figure 1: Crowd-aware analytics from the simulation for an eatery design. Left: environment layout with space semantics, Middle: color-coded trajectories of occupants – trajectories in *Red* show shorter traveled distances and evacuation times, whereas in *Blue* show longer distances and high evacuation times, and Right: occupant density heat map with high density in *Red* (problematic areas) compared to *Blue* ones.

ros Faloutsos. Joint exploration and analysis of high-dimensional design–occupancy templates. In *Proceedings of MIG*, page 35. ACM, 2019.

[Usman *et al.*, 2019b] Muhammad Usman, Davide Schaumann, Brandon Haworth, Mubbasir Kapadia, and Petros Faloutsos. Joint parametric modeling of buildings and crowds for human-centric simulation and analysis. In *International Conference on Computer-Aided Architectural Design Futures*, pages 279–294. Springer, 2019.

[Usman *et al.*, 2020] Muhammad Usman, Yi Mao, Davide Schaumann, Petros Faloutsos15, and Mubbasir Kapadia. From semantic-based rule checking to simulation-powered emergency egress analytics. pages 43–50, 2020.