Local Crowd Simulation and Authoring in Augmented Reality for Large-Scale Event Planning

Type d'offre : Thèse

Lieu de travail : Inria, équipe VirtUs, Rennes

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Context

Large-scale events — music festivals, sporting ceremonies, urban celebrations — are organised with increasing frequency and scale, and their planning routinely raises complex crowd management questions regarding layout, capacity and safety. Crowd simulation is one of the few tools currently available to support this planning stage, allowing organisers to anticipate crowd flows or evaluate evacuation procedures. However, it remains fundamentally limited to a global, external, desk-based perspective: a simulation is configured with parameters set at the scale of an entire site — density, flow directions, entry and exit points — run as a whole, and observed from the outside, typically through 2D visualisations or bird's-eye 3D renderings [Lemonari 2022]. This paradigm is well suited to large-scale planning, but it cannot capture how a crowd interacts with the specific physical layout of a venue, how attendees experience being immersed within it, or how staff should be trained to navigate and make decisions in complex, situated crowd configurations [Haghani 2023].

This PhD is part of PEAR, a collaborative ANR PRCI project between Inria, the Luxembourg Institute of Science and Technology (LIST) and the firefighter department of the Laboratoire Central de la Préfecture de Police de Paris (LCPP), with Hellfest Productions and Paléo Arts & Spectacles as festival partners. PEAR is driven by the hypothesis that combining realistic virtual crowd simulation with immersive eXtended Reality (XR) can fundamentally change how large-scale events are planned, by shifting the perspective from a global, external view of crowds to an embodied, first-person, on-site experience of crowd dynamics. Rather than configuring a simulation from a desk and observing its output from outside, users would be physically present within a virtually populated version of a real environment, through Augmented Reality (AR), and explore crowd scenarios locally and interactively, directly on-site.

The prototypes developed within PEAR will be confronted with concrete, real-world use-cases. The primary evaluation ground is the New Year's Eve celebration on the Champs-Élysées, led by the LCPP, which brings together over one million people in a dense urban environment each year and requires revising layout configurations, barrier placement and field team deployment for every edition. Findings will subsequently be generalised to the Hellfest and Paléo festival sites, to validate the applicability of the approaches developed in this position across different event formats, scales and physical configurations.

Objectives

Within PEAR, this PhD focuses specifically on how crowd scenarios can be simulated, authored and configured locally and interactively, directly on-site through AR — as opposed to being configured globally from a desk. It is structured around three complementary objectives.

The first objective is to design a local crowd authoring paradigm in AR: enabling users to move from a globally pre-computed crowd simulation, configured from plans and site maps, to a local, interactive exploration and configuration of crowd behaviours at a specific, physical location. This requires decoupling local crowd behaviour from global simulation consistency, so that local modifications — e.g., increasing density in front of a stage, or repositioning a barrier at an entrance — remain plausible without a full re-computation of the whole-site simulation.

The second objective is to ground this local authoring in the real environment itself, without requiring the full topology of the site to be known or modelled in advance. The candidate will explore how representations

such as Interaction Fields [Colas 2022] can be extended to infer local constraints from real-world semantic cues sensed through AR, and how on-site interaction paradigms can be designed to remain intuitive and accessible to non-expert users such as event organisers or safety officers.

The third objective is to contribute the underlying simulation and integration layer that makes on-site authoring possible in practice, in close collaboration with the AR-ready platform development led within PEAR: adapting Inria's existing crowd simulation tools to run at interactive frame rates on AR headsets, and helping define the shared data interface between local crowd authoring and the immersive data visualization developed by LIST.

The candidate will also lead the scientific evaluation of the resulting local authoring paradigm. First, assessing its usability and effectiveness for non-expert users — such as event organisers or safety officers — through measures including task completion time, NASA-TLX cognitive load, and SUS usability scores. Second, assessing the ecological validity of the resulting local simulations, by comparing behavioural measures such as minimum approach distances or avoidance trajectories [Olivier 2018, Berton 2020], and quantifying the biases these measures reveal — results that are essential to calibrate the ecological validity of the project's broader scenario evaluations, following a design study methodology [Sedlmair 2012]. These evaluations will directly feed the Champs-Élysées New Year's Eve use-case led by the LCPP, and be further validated and generalised at the Hellfest and Paléo festival sites.

Project Organisation

- Year 1: state of the art on crowd simulation, crowd authoring and AR-based interaction; contribution to the AR-ready integration platform and its shared data interface; first design of the local, on-site crowd authoring paradigm (initial demonstrator).
- Year 2: development and refinement of the local authoring paradigm, in particular the grounding of authored behaviours in real-world semantic cues; integration into the AR platform; first usability evaluation with non-expert users.
- Year 3: completion of the usability evaluation of the local authoring paradigm; contribution to the construction of the Champs-Élysées digital twin and to the immersive evaluation of crowd planning scenarios with the LCPP; participation in on-site evaluations at Hellfest and/or Paléo; thesis writing.

Requirements for candidacy

- Strong programming skills (C++ and/or C# recommended)
- Solid background in computer animation, computer graphics, or virtual/augmented reality
- Prior experience with Unreal Engine would be beneficial
- Interest in crowd simulation, human-computer interaction and experimental evaluation with human participants

Keywords and References

Crowd simulation; Local authoring; Augmented Reality; Human-Computer Interaction; Usability evaluation.

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