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Support for creation of augmented reality game stages based on real room layouts

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Augmented reality (AR) games integrate virtual content with real-world environments, enabling players to interact with digital elements situated in physical space. Unlike conventional video games developed within fully controlled virtual environments, AR games must continuously maintain spatial alignment between virtual objects and the surrounding physical world. This requirement introduces significant challenges to game stage creation, particularly in indoor environments where layouts are unknown in advance and subject to complex geometric constraints. Designers must consider furniture arrangement, walkable areas, and occlusion relationships while also coping with reconstruction noise, tracking drift, and limited computational resources on mobile devices. Consequently, AR game stage creation is often time-consuming and dominated by repeated trial-and-error during in-situ editing.

Most existing AR stage creation workflows rely heavily on first-person in-situ editing. Designers place and adjust virtual objects directly within the AR environment while observing the real space through a mobile device. Although this approach provides immediate spatial feedback and supports fine-grained alignment, it is inefficient for macro-stage planning. Global layout structure and spatial relationships between multiple objects are difficult to reason about from a first-person perspective alone. As a result, designers often rely on auxiliary methods such as paper prototyping to externalize ideas before AR implementation. However, this separation between abstract planning and AR execution introduces representation mismatch and further trial-and-error during the AR phase.

This thesis proposes a stage creation support method for mobile AR games based on real room layouts. The key idea is to introduce an intermediate representation that enables efficient macro-stage planning while maintaining consistency with real-world geometry. The proposed workflow integrates scene reconstruction, 2D top-down layout design, automatic 2D-to-AR mapping, and in-situ AR refinement into a unified process. By front-loading global layout planning into a low-cost 2D representation and bridging it to the real environment through geometry-aware mapping, the workflow aims to reduce trial-and-error and improve production efficiency and stage quality.

The workflow begins with scene capture and reconstruction. Users capture a video of the target indoor environment using a mobile device, which is processed offline using 2D Gaussian Splatting (2DGS). The reconstruction result is converted into a mesh-based geometric representation suitable for collision detection, support estimation, and spatial constraint evaluation in a game engine. This process is fully automated and does not require expertise in 3D modeling.

Based on the reconstructed mesh, a 2D top-down layout editor is generated. Designers arrange predefined game objects on this planar view to define macro-stage structure and relative spatial relationships without specifying object height or supporting surfaces. This stage allows rapid exploration of alternative layouts and reduces cognitive burden during early ideation.

After layout design, objects are automatically mapped into the real environment using a projection-based object-wise mapping strategy. Each object’s planar position is projected onto the reconstructed mesh to obtain an initial placement. To address reconstruction noise and local geometric irregularities, a local neighborhood is defined and multiple candidate placements are generated. These candidates are evaluated using an objective function that balances preservation of design intent, placement stability, and suppression of unreasonable inter-object overlap. Design intent preservation minimizes distortion of the original layout, stability evaluation estimates physical support from the environment, and overlap suppression reduces visually implausible interpenetration. The optimal candidate is selected for each object based on the combined score.

Following automatic mapping, designers refine object placement and gameplay details through in-

situ AR editing. Object position, rotation, and scale can be adjusted from a first-person perspective. To support gameplay authoring without scripting, the system provides a Trigger–Action logic model, enabling designers to define interactions by linking triggers to actions. Logic relationships are visualized and can be authored consistently across both 2D and AR stages. A Play Mode allows immediate gameplay validation, encouraging iterative refinement through seamless switching between editing and play.

A comparative user study was conducted to evaluate the proposed workflow. Eleven participants were recruited and divided into three groups. Group A used the proposed workflow combining 2D layout design, automatic mapping, and in-situ AR editing. Group B used a baseline workflow based on paper prototyping followed by in-situ AR editing. Group C served as third-party playtesters evaluating the completed stages. Participants in Groups A and B created AR game stages within the same real indoor environment under comparable conditions.

Quantitative analysis of production time and operation logs revealed that Group A completed macro-stage planning more quickly and achieved shorter overall production times. Although Group A performed a higher number of editing operations, these operations were concentrated within a shorter time span, indicating a more continuous editing process. Log analysis further showed fewer trial-and-error behaviors during the AR phase, such as repeated object manipulation and deletion. Participants using the proposed workflow also entered Play Mode earlier and more frequently, suggesting a more validation-driven design process.

Subjective questionnaire results supported these findings. Group A reported higher reuse intention and lower levels of frustration and perceived trial-and-error. Third-party playtesting evaluations showed favorable trends for stages produced with the proposed workflow, particularly in overall quality and immersion, while playability remained comparable across workflows.

In conclusion, this thesis presents a practical approach to AR game stage creation based on real room layouts. By integrating 2D macro planning with geometry-aware automatic mapping and in-situ AR refinement, the proposed workflow reduces cognitive burden and trial-and-error while improving efficiency and experiential quality. Although limitations remain in reconstruction accuracy and global consistency, the results demonstrate the effectiveness of separating macro-level planning from fine-grained AR editing. Future work will explore enhanced environment understanding and hybrid optimization strategies to further improve robustness and expressiveness.