AR Xmas – Marker-Based Augmented Reality Application

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This report documents the design, development, and evaluation of *AR Xmas*, a marker-based augmented reality (AR) mobile application developed using Unity and AR Foundation. The project explores how image tracking can be used to anchor virtual content in a real-world context, allowing users to interact with festive digital elements through their mobile device. The application was designed as a proof-of-concept, with a strong emphasis on technical stability, clarity of interaction, and alignment with coursework requirements.

Rather than focusing on visual complexity or advanced animation, the project prioritises a reliable AR experience that can be easily demonstrated and evaluated. This approach ensures that the core learning outcomes of the module—understanding marker-based AR, interaction design, and mobile performance constraints—are clearly addressed.

1. Project Overview and Concept

The AR Xmas project was conceived as a simple and engaging Christmas-themed AR experience suitable for mobile devices. The central concept involves scanning a printed marker to reveal a virtual Christmas tree positioned accurately within the user’s physical environment. Once placed, the tree can be interacted with using on-screen controls, creating a playful but intuitive user experience.

The festive theme was chosen to provide a familiar and visually appealing context while keeping the overall scope manageable. By limiting the experience to a small number of clearly defined interactions, the project avoids unnecessary complexity and allows the underlying AR techniques to remain the focus. This design choice also supports rapid onboarding, enabling users to understand and interact with the experience almost immediately.

From the outset, the project aimed to balance creativity with technical feasibility. The result is a compact AR application that demonstrates the practical application of marker-based tracking while still delivering an enjoyable seasonal experience.

2. Research and Background

Marker-based augmented reality uses computer vision techniques to detect distinctive visual features within a predefined image. Once detected, the system continuously tracks the position and orientation of the marker, allowing virtual content to be anchored consistently in the real world. This approach is particularly well-suited to controlled environments such as posters or printed materials.

AR Foundation was selected as the primary development framework due to its cross-platform design and integration with ARCore on Android devices. By abstracting platform-specific functionality, AR Foundation allows developers to focus on interaction design and content placement rather than low-level tracking implementation. This makes it an ideal choice for rapid prototyping and educational projects.

Research into effective marker design highlighted the importance of high-contrast imagery, asymmetric patterns, and non-repetitive visual features. These characteristics improve feature detection and reduce tracking ambiguity. QR-style markers naturally fulfil many of these requirements, which informed the visual design choices made for this project’s marker.

Another key consideration identified through research was the accurate specification of a marker’s physical size. AR Foundation relies on this information to correctly scale virtual content relative to the real world. Ensuring consistency between the printed marker and its digital configuration was therefore treated as a critical step in the development process.

3. Design and User Experience

The application was designed for portrait orientation to reflect typical smartphone usage patterns and to align with the printed poster layouts used for marker placement. Upon launching the app, users are prompted to scan the printed marker using their device's camera. Clear on-screen guidance helps users understand how to begin the AR experience.

Once the marker is detected, the virtual Christmas tree appears anchored to the marker's position. The placement feels natural and consistent, reinforcing the illusion that the digital object exists within the physical environment. Maintaining this sense of spatial stability was a key design goal.

The user interface is intentionally minimal and unobtrusive. Two large buttons are positioned at the bottom of the screen, labelled 'Lights' and 'Snow'. Their size and placement make them easy to access with one hand, while their clear labelling removes the need for additional instruction or explanation.

Simple instructional text is used to communicate the current tracking state. If tracking is lost, users are encouraged to re-align their camera with the marker. This feedback loop improves usability and reduces confusion, particularly for first-time users.

4. Technical Implementation

The AR Xmas application was implemented in Unity using AR Foundation alongside the ARCore XR Plugin for Android. An XR Reference Image Library was configured to include a single QR-style marker image, with its physical dimensions matched precisely to the printed A4 and A6 versions used during testing.

When the marker is detected, the ARTrackedImageManager triggers the instantiation of a prefab containing the Christmas tree model, lighting elements, particle system, and interaction controller. The prefab is anchored to the marker's pose, ensuring that it moves and rotates consistently with the tracked image.

To address model orientation issues, a child object within the prefab hierarchy is used to apply a rotation offset without affecting the overall tracking alignment. This approach provides flexibility while maintaining a clean separation between tracking logic and visual presentation.

User interactions are managed through Unity's UI system. Button presses are routed through a bridge script that communicates with the currently tracked AR instance. This architecture simplifies debugging and ensures that interaction logic remains robust even if tracking is temporarily lost or reacquired.

5. Testing and Performance

Testing was carried out on an ARCore-supported Android device under a variety of indoor lighting conditions. These tests focused on marker detection speed, tracking stability, and the responsiveness of user interactions. Particular attention was paid to ensuring that the experience remained smooth during prolonged use.

Performance optimisation played an important role in the development process. Particle counts for the snowfall effect were deliberately limited, and lighting complexity was kept to a minimum to maintain stable frame rates on mid-range mobile hardware. These optimisations helped prevent dropped frames and reduced the likelihood of thermal throttling.

Overall, the application demonstrated consistent performance during testing. Marker re-detection occurred quickly after temporary occlusion, and tracking remained stable when the marker was clearly visible and well-lit.

6. Evaluation and Reflection

The completed AR Xmas application successfully meets the objectives set out at the beginning of the project. It demonstrates a functional marker-based AR experience with clear interactive elements and a user-friendly interface. The project highlights the importance of careful planning and iterative testing when working with AR technologies.

One of the key lessons learned during development was the impact of marker design and physical sizing on tracking reliability. Small adjustments to these elements resulted in noticeable improvements in stability and user experience. This reinforced the value of early testing and incremental refinement.

While the current implementation is intentionally simple, it provides a strong foundation for future development. Potential enhancements include additional interactive decorations, audio feedback, animated elements, or support for multiple markers. Despite its limited scope, the project effectively demonstrates the core principles of marker-based augmented reality in a clear and accessible manner.