AR Wetlands: Water Pollution Simulator

Department of Computer Science and Engineering

CSE Senior Design, Fall 2025 | AR Wetland Watchers

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In partnership with the U.S. Army Corps of Engineers (USACE)

Background

The Interactive AR Table is an educational system that uses augmented reality to display 3D models and visual content on a physical tabletop. The tabletop provides a guided experience that includes animations, voiceover narration, and timed visual sequences. The main goal of the system is to raise awareness and help users better understand important topics related to civil engineering, water systems, and environmental impact. One of the key focuses of this project is highlighting how human activities such as construction and runoff contribute to water pollution, helping viewers understand the long-term effects of these actions. The project is sponsored by the U.S. Army Corps of Engineers (USACE) and is intended to be used in outreach and educational settings. By combining animations, 3D scenes, and audio narration, the experience helps communicate complex ideas such as stormwater runoff, erosion, and development impact in a way that is easy to follow. It is especially useful in settings where interactive demonstrations are limited, and visual context can enhance understanding. This product is designed for a wide range of users, including students, community members, government officials, and professionals in training. The primary audience includes individuals who may not have a strong technical background but need to understand the environmental and civil consequences of certain actions. For example, the AR Table may help explain to a community how urban development increases runoff and affects nearby water sources. It also will serve as a visual aid during briefings or demonstrations hosted by the U.S. Army Corps of Engineers or other educational institutions.

Key Requirements

The Key Requirements for the AR Wetlands Watchers project are focused on creating a self-contained, interactive Augmented Reality (AR) educational system that visualizes water pollution and environmental impact using a physical display.

This system combines a dedicated physical tabletop unit with a downloadable AR mobile application for Android. The primary requirements ensure that the application functions robustly in outreach settings by operating fully offline, accurately activating scenes based on physical markers, and providing a smooth, guided learning experience. High priority is also placed on safety, security, and performance metrics, such as fast startup times and proper data handling.

Key requirements:

- Educational Scenario Playback (displays animated AR scenes showcasing water pollution)
- Marker-Based AR Scene Activation
- Voice Narration for Educational awareness
- Physical Tabletop Unit
- Downloadable AR Application for Android
- Offline Operation
- App Startup Time (must be no more than 10s to open app and get started.
- AR Surface Detection Speed (should be within a couple of seconds to keep the experience engaging)
- No User Login Credentials
- Ask User for Camera Access
- Include a Privacy Policy
- Physical Display Table Edge Safety

Architectural Design

Device Hardware

Is the foundational layer, responsible for all interactions with the mobile device's physical hardware. It continuously captures essential real-time inputs, including the live camera feed, touch events from the touchscreen, and sensor data from inertial sensors. This layer leverages ARCore features for marker detection and surface recognition. The DHL provides these foundational raw data streams necessary for surface tracking and scene augmentation to the higher layers,.

Data Manager

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App

The App Layer (AL) is the highest level, delivering the entire visual and interactive experience to the user. This layer acts as the central controller, using Scene Management to coordinate educational flow and Marker Recognition to trigger the AR environment. It is responsible for accurately performing 3D Object Placement onto the physical tabletop and executing the Animation Engine to visualize pollution and water flow. The App Layer renders all augmented 3D models, displays the User Interface (UI), and processes user interaction logic (taps) to trigger specific educational content and responses

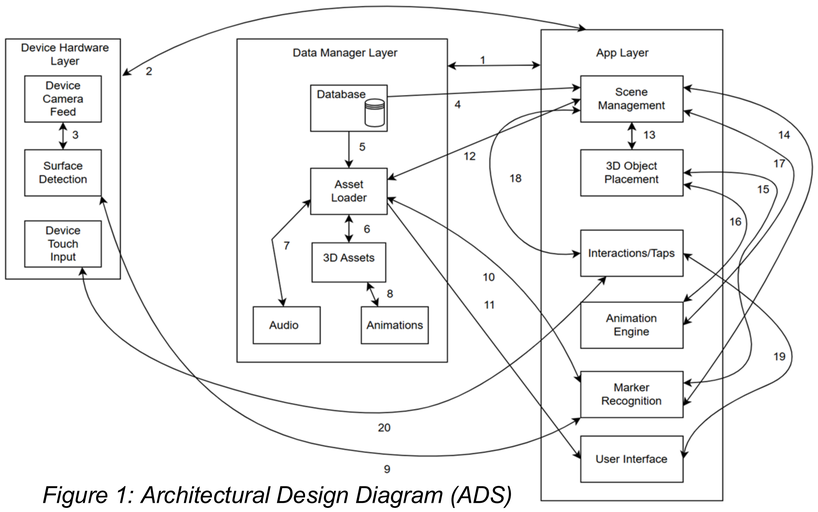

Figure 1: Architectural Design Diagram (ADS)

Implementation Details and Test Plan

AR System Implementation

- **Physical Table:**

  A 2.5 x 2.5 ft table with a printed marker strip was built to anchor the AR scene. When scanned, the 3D environment aligns with the table, allowing viewers to explore it from all angles.

- **Mobile App:**

  A custom Android app was developed that uses AR Foundation, ARCore, and the device camera for marker detection and scene playback. The app includes voice-over narration and was optimized for smooth performance on mid-range devices.

- **Scene Setup:**

  The Unity scene was developed using the Unity Engine - version 2022.3.1f1 - uses low-poly assets from the Unity Asset Store, forming four zones: Neighborhood, Factory, Construction Site, and Main Road. Each of these zones illustrate human impact on water pollution. The experience plays automatically with synchronized visuals, animations, and narration.

Figure 2: AR Scene Setup

Figure 3: Physical Table

Figure 4: AR Wetlands App

Testing and Validation

- **Testing Process:**

  Testing was conducted on multiple ARCore-compatible Android phones. Each trial involved scanning the marker, observing alignment accuracy, and evaluating animation playback and audio synchronization.

- **Results:**

  The AR environment remained stable and properly scaled during testing. Voice-over narration matched visual cues, and performance stayed smooth under various indoor lighting conditions.

- **Troubleshooting:**

  If the AR scene appears misaligned or duplicated, close and reopen the app. Then scan the marker at a slight angle and slowly back away to let the scene align.

  This issue results from Unity AR platform limitations on some mobile devices.

Conclusions and Future Work

Conclusion

- As a team, we were able to fulfill the general requirements of our sponsor's needs (USACE) in delivering a more enhanced version of what was previously done successfully in Augmented Reality.

Future Work

- Would need to create captions for the narration that plays per scene to deliver another delivery format in getting the message across.
- Polish up scene with more lively animations and dedicated sounds to each scene.

References

1. Android Developer Documentation. Google, 2025, https://developer.android.com/training/data-storage/use-cases.
2. Android Developer Documentation. 2025, https://developer.android.com/training/permissions/requesting.
3. Android Developer Documentation. Google, 2025 https://developer.android.com/topic/architecture/data-layer/offline-first.
4. Glasgow Caledonian University. "Data Protection Privacy Policy, Version 1.2." Aug. 2020, https://www.gcu.ac.uk/__data/assets/pdf_file/0018/38700/data20protection20privacy20policy20v1.220august202020.pdf.
5. Riesenmy, Jeff. "Addressables: Planning and best practices." Unity Blog. 2023, https://unity.com/blog/engine-platform/addressables-planning-and-best-practices.
6. Termly Legal, LLC. "Google Play Store Privacy Policy Updates." Termly. 2022, https://termly.io/resources/articles/google-play-store-privacy-policy-updates/.
7. Walk With Pic. "GDPR vs. CCPA vs. CPRA: Data Protection Compliance Guide." Walk With Pic. 2023, https://www.walkwithpic.com/blog/gdpr-ccpa-cpra-data-protection-compliance-guide.