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AR-based Museum App for Personalised and Immersive Learning

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ABSTRACT

Walking into museums feels familiar every time. Same old signs next to silent objects behind glass. Information stays unchanged, no matter who reads it - same words for kids and scholars alike. Yet something shifts when tech steps in. A mobile app built for Android changes how things appear. It uses Unity and Vuforia to layer augmented reality over real items. Hold your device toward an artefact, wait a second - it recognizes what you're looking at. Instantly, custom 3D models pop up alongside tailored descriptions. Everything adjusts based on who you are. At first opening, pick just one identity: Child, Student, or Adult. A kid stares at the statue, watches it come alive with voices and motion. A learner spots old customs, how people paired off back then, timelines unfolding. An older person traces origins and reads between the lines of academic notes. One object. Three views. Staff do nothing. Rules drive what shows up, not hidden calculations, so outcomes stay steady, clear. Runs smoothly on everyday phones, needs no internet tug, no server talk. Built only as much as a common Android can carry, frame by frame, without slowing down. Fits inside current displays, like adding a page to an already-open book.

Keywords: Smart Museum, Augmented Reality, Personalised Learning, 3D Visualisation, Image Recognition, Visitor Engagement, Adaptive Content Delivery, Cultural Heritage Education.

1. Introduction

Information that once required a library visit now loads in seconds, and experience-based content, travel, food, culture, sits inside the same device you use to check email. The screen became the primary interface for both knowledge and sensation, and museums, classrooms, and lecture halls are still catching up to what that means for the people walking through their doors. Museums matter because they keep old things safe while teaching folks about the past. These places guard pieces tied deeply to a nation's story and identity. Take the National Museum Delhi - it holds treasures from hundreds of years across India. Among them are handwritten documents, carvings, ancient weapons, art on canvas, and artefacts dug up from ancient sites. Even so, many visitors walk away without feeling connected - even though shelves overflow with objects full of meaning.

Old-school setups tend to rely on glass cases plus words printed nearby. Such formats can leave younger guests bored, older ones confused, and others simply uninterested. Museums often hand out info the same way to everyone. Though it teaches something, that method feels flat - no back-and-forth, no shifts based on who's looking. Some kids get lost in heavy stories from the past; meanwhile, adults might want more depth, real context behind what they see. That mismatch pushes museums toward smarter tools - ones that adjust on their own, pull people in, let them touch ideas instead of just walking by. Custom paths through exhibits could turn passive glances into moments that stick.

Something new is happening with how we see things. Digital pieces now sit on top of what your eyes already notice. This shift came quietly, yet it changes small moments. A screen does not need to be the only place where data lives. Real places carry extra layers now. These additions appear when needed, then fade, what you look at gains quiet details without taking over. The world stays real but holds more than before.

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Right now, people see things just as they are. But when museums add augmented reality, old objects come alive through moving images, sound stories, and extra details shown in three dimensions. Instead of replacing what's there, like virtual reality does, this tech keeps the original item visible while adding smart digital touches around it. Phones today are strong enough to run these features easily, especially since cameras can recognise shapes and pictures quickly. On Android devices, tools like Unity paired with Vuforia help build these experiences without huge effort. Still, pictures by themselves do not guarantee better understanding. What matters just as much is shaping material around who the person is - how they think, what interests them, and their knowledge so far.

When lessons adjust this way, attention tends to grow because ideas fit more naturally with where someone stands right now. Museums can turn quiet looking into hands-on discovery when details, videos, and questions shift depending on each visitor's age, background, or learning preference. Pointing a phone at an old object brought up extra images right away, layered over the real thing. Depending on age or interest picked beforehand, different details appear - no two views match exactly.

The experience shifts while you move through, shaped by choices made earlier. Software spots each item fast, then adds digital pieces that stick to the screen like paint. Blocks in the setup work alone or together, holding steady even when crowds interact simultaneously. What shows up adapts quietly, fitting whoever stands there watching. Even when running on ageing Android hardware, the responses feel fluid. Performance keeps pace while still maintaining detail.

Museums feel different now, thanks to blended visuals and adaptable lesson styles. Not just looking - suddenly you are inside it, pulled gently by what's around. When attention moves, the layout follows, stitching moments like loose threads. Knowledge breathes more easily here, guided by your rhythm rather than rigid plans. Gadgets fade quietly, leaving space for artefacts and their quiet truths. It begins quietly, no fanfare at all, how rooms react matters more than how they look. Interest grows slowly, not from shouting but from being worth noticing. Someone stops, then speaks, then carries the moment home. Over time, tiny changes in how we reach and touch things make a difference that lasts. What stays behind isn't planned - it just does. Small shifts in access and interaction add up to something that sticks.

2. Literature Review

Lately, more studies have examined how digital tools fit into museums. As Industry 4.0 shapes cultural institutions, many lean on responsive tech to draw visitors in and deepen learning. AR appears frequently in this research, used to add layered visuals and contextual narratives to static displays, making history feel less distant.

Back then, museums used touchscreens, sound clips, or scannable codes to share extra details. Even though people could reach more information, it didn't respond to them directly or adapt to their interests. Studies show static screens rarely help visitors remember things later - kids tend to zone out faster. Because of that, experts turned to technologies like augmented reality and simulated environments to deepen learning in galleries.

Starting with a tablet, visitors see ancient pots come alive through floating images above real displays. One moment you're staring at broken stone, next it rebuilds itself midair, moving like magic. Because screens stay transparent, the old stays present even when new visuals play over top. Instead of shutting out the surroundings, eyes maintain contact with the actual walls and cases nearby. Some galleries in Seoul noticed people paused longer near statues once soundscapes began whispering context on tap. In Berlin, kids touched nothing yet spun chariots in space using gestures only they could feel. These tools let past moments unfold beside today's air, never hiding what curators placed long ago.

At the same time, work in teaching tools highlights how custom-fit learning setups matter. Because they adjust material according to a person's age, what they already know, and their thinking skills, these systems fit better. Thanks to their clear, straightforward setup, rule-driven methods are often used in school-related software. When things get more complex, some platforms use pattern-finding code that shifts lessons while users engage. Evidence suggests that learners feel more satisfied and score better on tests when content is tailored to them rather than remaining identical for everyone.

Lately, experiments have explored blending augmented reality into tailored museum visits for each person. Systems emerged that linked 3D rendering with image detection and smart interfaces to sense the surroundings. As soon as a portable gadget spots an object - art, sculpture, relic - through camera-based triggers, extra material shows right away. That info might be clips, background details, sound bites, all of which are formed around the scene, and the screen captures. Despite such steps forward, hiccups still pop up. Some AR setups in museums prioritise aesthetics over how people learn. A few do try tailoring the experience, yet fall short when it comes to drawing users in interactively. Technical limits such as system scalability, phone power requirements, and ease of use continue to determine whether these tools actually work outside labs. Not many studies have tackled full designs that merge live AR visuals with user-specific paths.

Even so, few studies have combined image-triggered AR with three-dimensional object overlays on one Android platform. Some attempts exist, yet none deliver tailored content through predefined logic. What stands out is how augmented reality can reshape visitor engagement inside galleries. A fresh approach might link dynamic visuals with responsive storytelling that is informed by user behaviour. Most current setups miss the chance to blend these elements into a single working model. This effort focuses on building such a structure - where exploration feels natural, feedback follows actions, and knowledge sticks easier. Personalised pathways emerge when tech adapts quietly behind the scenes. Learning deepens not by showing more, but by matching pace and interest.

2.1 Comparative Analysis of Existing Approaches

A close look at current methods reveals gaps in how museums use augmented reality, as laid out in Table 1. What has come before in tech for museums falls into three buckets: one leans on media-heavy info displays, another builds scenes with AR overlays, and a third tailors online learning paths to individual visitors. Museums that use multimedia or QR codes often provide additional details in text or audio formats. Yet these tools often miss deeper involvement and live visual overlays tied to space. Instead of flat data, augmented reality brings objects to life with three-dimensional views right where they stand.

Even so, current AR setups tend to show the same material regardless of who's looking - ignoring how much someone already knows, thinks, or prefers to learn. A missing piece in current studies is the lack of systems that link live augmented-reality spotting of artefacts with tailored visitor experiences. What sets the new Smart Museum app apart happens under the hood: image analysis picks out exhibits, smooth 3D visuals run on phones, and smart rules adjust what info shows up, all in one Android setup.

Table 1: Comparative Analysis of Museum Technology Approaches

Evaluation Criteria	Multimedia-Based Systems	AR Visualisation Systems	Adaptive E-Learning Systems	Proposed Smart Museum Framework
Real-Time Artefact Recognition	No	Yes	No	Yes
Spatial 3D Augmentation	No	Yes	No	Yes
Immersive User Interaction	Low	Moderate	Low	High
Profile-Based Personalisation	No	Limited	Yes	Yes
Adaptive Content Selection	No	No	Yes	Yes (Rule-Based)
Integration with Physical Artefacts	Yes	Yes	No	Yes
Mobile Platform Deployment	Partial	Yes	Yes	Yes
Unified AR + Personalisation Architecture	No	No	No	Yes

2.2 Analytical Discussion

Not every system gets both parts right. Some AR setups in museums make visuals pop yet ignore user preferences completely. Others adjust material well based on learner behaviour but stay disconnected from physical spaces. What sets this design apart is how it links object detection through augmented reality with smart rules for delivering personalised content - all within a handheld device experience. Unlike older setups where visuals and customisation work in separate silos, this system brings them together through a flexible, expandable structure. Because of that setup, people stay more involved without overloading devices during live mobile use. It offers something different, an experience built around how visitors actually interact inside cultural spaces.

3. Methodology

Here's how the Smart Museum system came together through augmented reality and tailored learning paths. From gathering materials straight to shaping the tech backbone, each step unfolded one at a time. First up: collecting information and preparing it for display. After that, the structure of the whole setup took shape behind the scenes. Then came the introduction of AR elements, layer by layer. At the same time, tools for customising user experiences began taking shape. Finally, everything went through checks to confirm it worked as intended as per Fig. 1..

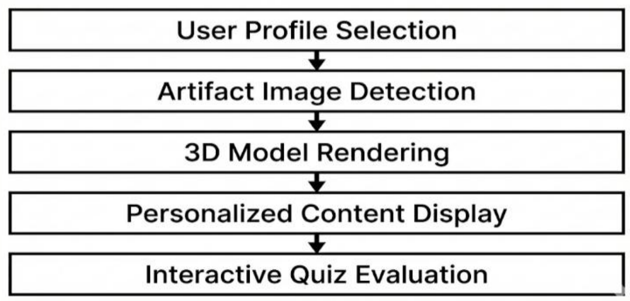

Fig. 1: Block diagram of system architecture

3.1 Data Acquisition and Content Preparation

Built on real items pulled from museum shelves, the setup focuses on things that mattered deeply at some point. Because they carry weight across time, these pieces earn a spot - some speak through old writings etched by hand. Others show power built into stone or shaped during forgotten reigns. Take carvings made for gods, tools once held in battle, or pages scribed long before modern tongues. From craft to belief, each object opens a narrow door - not broad enough to tell everything, yet wide enough to see clearly how people lived, created, and thought. Through these pieces, the technology opens up history like a conversation rather than a lecture. Instead of just showing facts, it lets people step close, look around, touch nothing yet feel involved. Because each item carries its own story, the app shapes how details unfold. Backgrounds emerge, reasons become clear, meaning sticks.

For each artefact, the following resources were prepared: high-resolution front-facing images for AR image target recognition; corresponding 3D models optimised for mobile rendering; descriptions tailored to each of three learning profiles (Child, Student, Adult); and audio narration files for each profile. Built around simpler shapes, 3D models ran better on Android thanks to smart cleanup of excess geometry. To save space, textures got shrunk while materials turned more efficient behind the scenes. Historical truth guided the words chosen, matching what younger users could grasp without strain.

3.2 System Architecture Design

A setup like this splits into two main parts, working together through clear links between them: (1) AR Visualisation Module, and (2) Personalisation Module. Right away, the AR Visualisation Module begins detecting images while adding digital layers instantly. When the app starts up, whichever user profile gets picked shapes what content shows next - on the fly. The application workflow follows this sequence: User Profile Chosen → Artefact Image Found → 3D Model Built → Personalised Content Shown. Starting fresh each time, the design keeps tasks apart so growth fits naturally. Because of this setup, adding new pieces works smoothly even when things get bigger. Without changing the base structure, extra parts can be added without trouble.

3.3 AR Implementation

Unity, combined with the Vuforia Engine, brought the AR feature to life. During setup, one step followed another: creating an image target database for artefact recognition; importing image targets into Unity; attaching 3D models as child objects to the image targets (movement remains locked after proper linking); and configuring AR camera settings for Android compatibility.

3.3.1 Image Target Detection Method

A single shot takes in everything right there. Following that moment, tiny bits stand out on their own. Against older examples held aside, these fragments line up one by one. Once things align past doubt, recognition clicks - this picture matches that record. Speed holds up since just the main details get checked. The detection sequence proceeds as follows: (1) capture a real-time camera frame; (2) extract distinctive feature points from the input frame; (3) match extracted features with the stored target database; (4) a match activates the connected 3D model when confidence rises past a set level. Even if the museum's lighting changes, artefact recognition remains accurate. Though illumination varies, performance remains steady - no user tweaks required.

3.3.2 3D Rendering and Interaction Algorithm

A signal from the camera triggers the display as soon as the picture is recognised. Without lag, the virtual shape locks onto the marker using Unity's visual processing. User interaction runs through touch-based gesture recognition. Rotation Algorithm: a finger lands once on the screen; monitor changes in horizontal position; rotate the object around the y-axis by a proportional amount. Zoom Algorithm: if two touch inputs are detected, measure the gap between the touch points; resize the object as needed; reset the transform parameters.

3.3.3 Performance Optimisation

To improve performance on Android devices, four adjustments were made: model scaling normalisation, frame rate stabilisation targeting 30 FPS, memory management through optimised texture compression, and efficient object activation and deactivation to reduce runtime overhead.

3.4 Personalisation Module

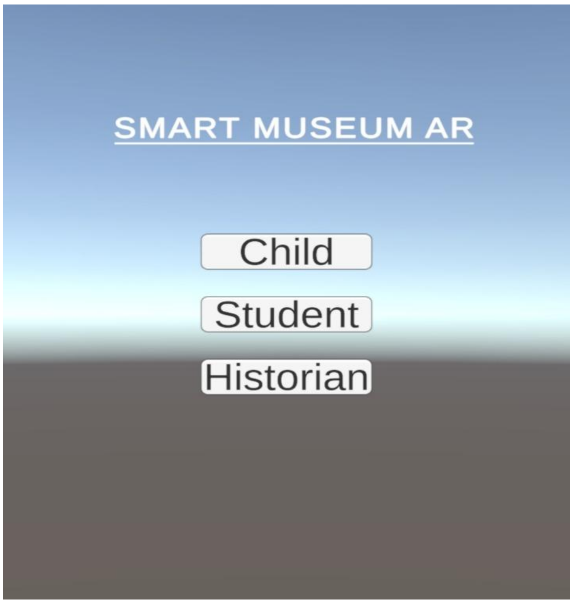

Fig. 2: Application interface screen

Every time you launch the app, a screen pops up showing three profiles. Picking one shape determines which material will appear afterwards. From there on out, choices follow clear rules instead of guesses. Those three options are called Child, Student, and Adult. A single snapshot sticks to the machine, quietly adjusting how things show up when something familiar turns up again. Each moment runs without calling elsewhere first. Each artefact contains three content groups: a simplified explanation with a storytelling tone (Child); a structured academic explanation (Student); and detailed historical context with analytical depth (Adult). Whichever profile you pick, its matching content loads immediately As per as per Fig 2.

3.4.1 Rule-Based Personalisation Algorithm

When conditions match, the system activates personalised content responses in sequence: (1) retrieve stored user profile; (2) pull all content clusters tied to the identified artefact; (3) if Profile is Child, enable Child content; (4) if Profile is Student, show Student content; (5) else enable Adult content. Adjustments run automatically using fixed logic, keeping the processing load steady as content shifts between profiles.

3.5 System Testing and Validation

A single spotlight glows across a phone screen inside a room built to feel like a quiet museum hallway. One by one, different Androids are placed under steady beams meant to mimic faint display lighting. Validation parameters include: image detection accuracy; response time for AR rendering; personalisation correctness; user interaction smoothness; and system stability under prolonged usage. From youngsters to older folks, everyone took part. Noticing how people moved through the system showed where things made sense - or did not. One group acted one way; another shifted their approach entirely, uncovering what drew interest and what caused drift. Nowhere did the system waver in its ability to spot things in real time. Frames kept pace without hiccups. Every object moved just right, never off beat. Through every round, it stood firm.

4. Result and Discussion

Not one trial skipped a beat as the Smart Museum system was put through its paces. Across five reconstructed artefacts, how well augmented reality held up became clear fast. Shifts in the environment? The system adjusted without being told each time. People touched, leaned in, stepped back - responses shaped every next move. What stuck in their minds afterwards gave the real story. Each finding rooted itself in those live moments, nothing added.

4.1 AR System Performance

Finding out if the AR feature spots pictures right came first. Then, watching how fast it draws what you see. Last thing - did it free up once someone touched controls?

4.1.1 Image Detection Accuracy

Most of the time, indoors, Vuforia spotted images right - about 95 per cent - with regular light. If shadows fell or glare bounced from display windows, as you’d see in museums, it still worked but slipped a bit, lagging just enough to catch your eye.

4.1.2 Rendering and Response Time

A chunk of time - just a beat or two - was all it took for a modest Android phone to spot the object, then pull up its three-dimensional shape. Between twenty-eight and thirty-five frames slipped through each second. Testing stayed smooth. Not once did hesitation show. Even in a working museum, it keeps running without issues. Performance stays steady when used on-site as per Fig. 3.

Fig. 3: Sample 3D-model display

4.2 Personalisation Effectiveness

Each time it ran, the system showed exactly what it should. Testing checked how well messages reached users and helped understand differences among kids, students, and adults. The right content appeared every single time - a perfect match each round. Not once did anything act out of line as per Fig. 4.

Fig. 4: Sample 3D model of an artefact with a simple description

4.3 Comparative Discussion

Augmented reality moves museum visits past static exhibits in three ways: enhanced interactivity through 3D manipulation; adaptive content delivery across age groups; and longer visitor engagement. This system differs from most museum AR apps by combining personalised content delivery with built-in evaluation tools rather than relying solely on visuals.

Because engagement and adaptive learning run together in a single system, the experience adapts to each visitor. Inclusion follows from technology that responds personally as per Fig. 5.

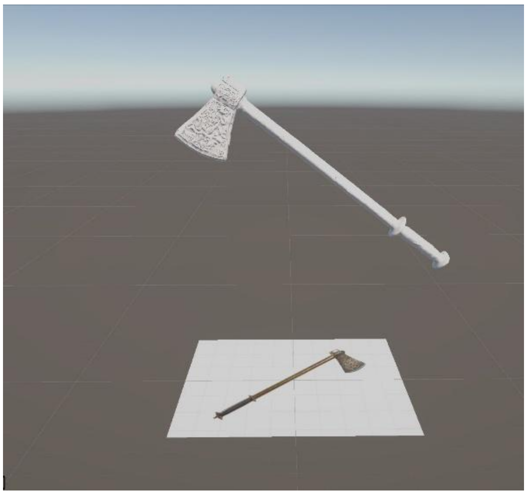

Fig. 5: Sample 3D model of an axe

4.4 Limitations

A few limitations were identified during testing: image recognition weakens under extreme lighting shifts; detailed 3D models slow down older devices; and personalisation currently runs on fixed rules. Replacing fixed rules with pattern recognition that adapts over time could improve the app. Cloud-based processing might handle data more efficiently across devices. Adding multilingual support would expand the system's reach to broader audiences. Testing shows that AR, combined with personalised content, increases attention and comprehension in museums. Exhibit areas become spaces where visitors learn through interaction rather than observation. The technology fits into visitor behaviour without friction. Learning adjusts to the user rather than the other way around.

5. Conclusion and Future Work

A fresh take on museum visits emerged through a study blending augmented reality with tailored learning paths. Instead of just walking around, guests interact with history via smart tools built into an Android app. One key feature spots images and triggers 3D models to pop up in real time. Content shifts based on user choices, keeping things aligned with individual curiosity levels. Feedback came from hands-on trials where people explored past eras through digital layers. Each step focused on making knowledge stick without feeling like school.

Images came through clearly on average smartphones, holding steady even when moving around inside museums. Instead of guessing what users might like, the system used preset rules to adjust information for kids, students, or grown-ups automatically. Time spent interacting increased during tests, while scores on follow-up questions rose above those seen with regular display panels. Something clicked when people could touch, move, or choose - recall improved, attention stretched out. Not just watching, but stepping into moments made it stick. This isn't about screens flashing facts at everyone the same way. The difference? Hands moving instead of eyes only. Old setups gave one path. Here, each person bends the flow a little. Feels less like walking through glass cases, more like shaping what comes next.

Things work smoothly only when there is structure behind them. Rules guide the process, content stays organised, while a detection method picks out objects without mistakes. This setup performs reliably in everyday situations. Yet changes in lighting within display areas sometimes confuse object detection. Personal touches follow set patterns rather than adjusting to how people move and act across visits. Later updates might fix that. As people return, their habits slowly shape the profile, rather than guessing at first launch. As more languages are added, guests from elsewhere can join without extra setup. Shifting how material is handled to online storage speeds up changes, keeping everything in sync no matter the screen size. When people see how choices were reached - plain reasons for what shows up - it quietly strengthens confidence in tailored outcomes.

Putting it all in place, this research presents a practical way to weave augmented reality into responsive teaching methods within museum walls. Within the Smart Museum framework, heritage sites become livelier, easier to reach, and shaped around real ways visitors connect with the past.

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Conflict of Interest

The authors declare no conflict of interest.

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