Development and Functional Evaluation of a Marker-Based Augmented Reality Application for Selaawi Bamboo Crafts

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***Abstract*—Bamboo crafts constitute a local cultural and economic asset in Selaawi, Garut, Indonesia. However, conventional posters and product photographs provide limited support for observing the three-dimensional form of a craft item. This paper presents the development and functional evaluation of an Android marker-based augmented reality application for promoting selected Selaawi bamboo crafts. The application was developed with the Multimedia Development Life Cycle method through six stages: concept, design, material collection, assembly, testing, and distribution. Four representative craft products were prepared as 3D assets: a bamboo flute, *nyiru* (traditional winnowing tray), tissue box, and miniature house. The assets were integrated with Unity and Vuforia image targets, while a promotional poster was designed to provide both product information and recognizable visual features for tracking. The prototype was assessed through ten documented verification scenarios, comprising eight end-user functional tests and two integration-validation checks. Nine of the ten verification scenarios passed. Seven of the eight end-user functional tests passed, while the multi-target scan did not achieve reliable simultaneous detection and rendering. Both integration-validation checks passed. The resulting prototype demonstrates a feasible interactive promotional medium that enhances localized craft storytelling and provides added cultural-economic value for bamboo artisans in Selaawi.**

Keywords—augmented reality, Android, bamboo crafts, image target, multimedia development life cycle.

I. Introduction

The digital transformation of promotional media has encouraged businesses and cultural-product providers to move beyond static images and text-based descriptions. Digital product-visualization media can influence how consumers evaluate physical products [1]; however, conventional promotional materials such as posters, brochures, and standard online photographs often provide limited opportunities for audiences to understand the form, texture, scale, and functional characteristics of physical products. This limitation is particularly relevant for handcrafted products, whose value is often embedded not only in their function but also in their material, visual detail, and cultural meaning [2], [3].

Augmented Reality (AR) has emerged as a technology that can enrich physical promotional media by overlaying digital content onto real-world objects or images. Through mobile devices, AR enables users to access three-dimensional visualizations, interactive information, and contextual digital content in real time [4], [5]. In recent years, AR has been widely applied in learning and product-promotion contexts to provide more interactive visual experiences because it can provide more immersive and engaging user experiences than conventional media [6], [7]. In the context of product promotion, AR can support audiences in examining a product from multiple perspectives and receiving additional information without requiring the physical product to be present.

Despite its potential, the development of AR-based promotional media involves several technical considerations. A reliable AR application requires suitable digital assets, an appropriate interaction mechanism, a mobile deployment environment, and image targets that can be recognized consistently by the tracking system. In marker-based AR, the quality of the image target is particularly important because the target must contain sufficient visual features to enable stable detection and tracking. Therefore, the design of an AR promotional system should balance aesthetic communication, product identity, and technical detectability.

This study investigates the use of marker-based AR as an interactive promotional medium for local craft products. The proposed approach integrates product documentation, three-dimensional assets, poster-based image targets, and an Android AR application developed using Unity and Vuforia. Rather than replacing conventional promotional materials, the AR application is designed to extend the function of posters by allowing users to scan a visual target and access a three-dimensional representation of the promoted product.

The case study focuses on bamboo crafts from Selaawi, Garut Regency, Indonesia. Selaawi is known for its bamboo-craft tradition, which includes household utensils, decorative products, and musical instruments. These products represent local knowledge, manual craftsmanship, and the use of bamboo as a locally available material [8], [9]. Previous work related to bamboo-craft promotion in Selaawi has highlighted the importance of digital marketing while also identifying limitations in conventional product visualization, particularly when photographs do not adequately communicate product details [10]. Therefore, AR offers an opportunity to provide a more interactive and visually informative promotional experience for bamboo-craft products.

This paper presents the development and functional evaluation of an Android-based AR promotional prototype for selected Selaawi bamboo crafts. The objectives of this study are: 1) to create representative three-dimensional models of selected bamboo-craft products; 2) to integrate the models into a marker-based AR application using Unity and Vuforia; and 3) to evaluate the core functionality of the application through black-box testing. The contribution of this work is an implementation-oriented AR promotional prototype that demonstrates how local craft information can be delivered through interactive mobile visualization. The evaluation focuses on technical functionality, including camera access, marker detection, model rendering, interaction, offline operation, and tracking stability.

II. Methods

The project followed the Multimedia Development Life Cycle (MDLC) approach because the work involved the coordinated preparation of visual materials, 3D assets, an interactive Android application, and a physical promotional poster. The adopted process consisted of six stages: concept, design, material collection, assembly, testing, and distribution. This sequence is consistent with AR multimedia-development studies that organize content planning, asset creation, application integration, evaluation, and delivery in a traceable lifecycle [11]–[14].

A. Concept and Requirement Definition

The target users were identified as members of the public, potential visitors, students, artisans, and local stakeholders who may encounter craft products through an exhibition, village-office display, or promotional activity. The application was intended to provide a direct, lightweight visual interaction: a user opens the Android application, points the camera at a designated poster panel, and receives a corresponding 3D representation of a bamboo craft product.

The prototype scope was limited to promotional visualization. It did not include a shopping cart, online transactions, iOS deployment, special AR hardware, or a web version. The project used four representative product categories to keep the 3D modeling and mobile testing tractable: bamboo flute, *nyiru* (traditional winnowing tray), tissue box, and miniature house. The expected output was an Android Package Kit (APK) coupled with a poster that acts as a promotional medium and an image target.

B. Design and Material Collection

Product photographs and contextual information were collected from a bamboo-craft setting in Putra Jawa Village, Selaawi. The photographs served as visual references for geometry, proportions, colors, and textures. Where direct documentation was unavailable, visually comparable reference assets were used solely for prototype visualization. External assets were selected only when their source and reuse permission could be documented. The aim was to create recognizable digital representations rather than manufacturing-grade three-dimensional replicas.

Blender was used to prepare 3D models and export the selected assets in Filmbox (FBX) format. A design constraint was to maintain recognizable craft characteristics while controlling model complexity for mobile rendering. The flute model represented the cylindrical body and finger holes; the *nyiru* model represented a circular woven tray; the tissue box represented a woven rectangular container; and the miniature house represented its roof, wall, and support form. The poster and image-target panels were designed in Canva using a combination of product image, title, and concise explanatory text.

The implementation workflow is shown in Fig. 1. Craft documentation provided references for both the poster panels and the 3D assets. The 3D assets exported from Blender were imported into Unity, while the poster panels were uploaded as Vuforia image targets. Unity and Vuforia then linked each target to its assigned 3D object before the application was exported as an APK.

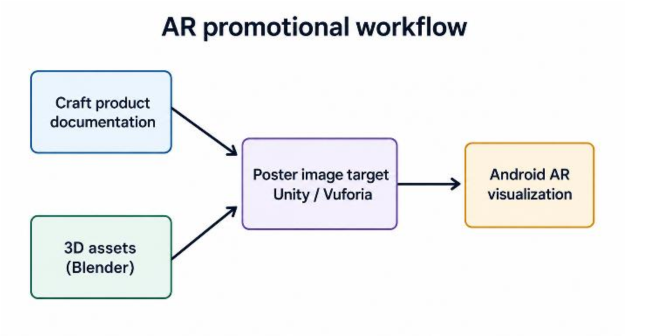

Fig. 1. Simplified workflow from craft documentation to Android AR visualization.

C. Assembly and Technical Integration

The assembled prototype used Unity 2022.3.4f1 as the application environment and Vuforia Engine as the image-target tracking component. Unity provides an environment for importing 3D assets, arranging the scene, and producing an Android application package, while Vuforia provides image-target recognition functions for AR development [15], [16]. Each image target was assigned to a corresponding model so that a detected target triggered the appropriate craft representation in the AR camera view. Table I summarizes the main prototype components and their implementation roles.

The first target design obtained a low Vuforia rating of two stars. It was revised in Canva by adding clearer visual composition and more distinctive image features. The revised target obtained a five-star rating in the Vuforia database and was used in the final prototype. This iterative adjustment was an important practical step because target quality affects the likelihood that the camera can identify the intended visual reference.

The final application was exported as an APK. The interaction sequence included launching the application, granting camera permission, pointing the camera at a poster panel, rendering the assigned 3D model after target detection, and changing the viewpoint by moving the device. Basic touch interaction enabled the user to inspect the displayed object more closely. The application was designed to operate without an active Internet connection after installation.

D. Functional Evaluation

The functional evaluation used documented black-box scenarios. Black-box testing checks observable input-output behavior against an expected function rather than examining the internal implementation. It is therefore appropriate for confirming whether a mobile AR application opens the camera, detects a target, renders the expected object, and responds to basic interaction conditions [17], [18].

The prototype was assessed through ten verification scenarios, comprising eight end-user functional tests and two integration-validation checks. Functional testing was conducted using a Samsung Galaxy A35 5G smartphone as the target Android device. The device camera was used to scan the printed poster panels under normal indoor lighting and a reduced-light condition. The evaluation focused on observable functional behavior rather than benchmark performance measurement.

The test inputs involved camera access, marker direction, touch interaction, offline operation, perspective changes, lighting conditions, and attempts to scan several targets at once. Results were recorded as pass or fail based on the observed output. The test set was intentionally functional in nature and did not constitute a formal usability or benchmark-performance experiment.

TABLE I. PROTOTYPE COMPONENTS

Component	Implementation	Purpose
3D viewing	Interactive 3D visualization	3D viewing
Poster + trigger	Product information and AR trigger	Poster + trigger
AR rendering	Marker-based AR rendering	AR rendering
Mobile demo	Android mobile deployment	Mobile demo

III. RESULTS AND DISCUSSION

A. Poster and Image-Target Output

The poster was designed as a four-panel visual arrangement, as shown in Fig. 2. Each panel presents a selected craft product and functions as a target for one AR model. This design makes the poster usable even before the application is installed because it still contains basic product information. After installation, the same poster becomes an interactive trigger that links the physical display to a digital 3D view.

The revised target rating indicates that the final panels offered more features for recognition than the initial version. It is important to interpret this result carefully: a high database rating is an implementation indicator, not a guarantee of performance in every environment. Actual tracking may still depend on camera quality, distance, angle, lighting, motion, and the physical quality of the printed poster. The project therefore retained a direct functional test to confirm that the target could be used in the available device setting.

A. Android AR Visualization

The final application produced a direct augmented view when a designated poster panel was detected. The image target was placed in the camera view, and the assigned 3D craft model appeared above the target. The content was designed to support observation from different perspectives rather than to imitate a complete commercial product catalog. The screenshot in Fig. 3 illustrates the rendering of the miniature-house model after marker detection.

Fig. 2. Poster panels used as visual information elements and image targets.

The model-to-target mapping provides a predictable interaction: each target corresponds to one craft object. This one-to-one mapping simplified debugging and supported clear testing of whether the intended target produced the expected model. It also limited the initial complexity of the application. A more advanced future version could include richer product metadata, animated craft-making steps, sound, pricing or supplier links, and multiple language options.

Fig. 3. Example AR rendering of the miniature-house model after image-target detection.

B. Black-Box Results

The functional evaluation results are summarized in Table II. Nine of the ten documented verification scenarios passed. Seven of the eight end-user functional tests passed, while the multi-target scan did not achieve reliable simultaneous detection and rendering. The two integration-validation checks, namely target revision or upload and model-target assignment verification, also passed.

The functional pass rate was calculated as 9 divided by 10 scenarios, or 90%. This number must be interpreted only as a summary of the test record: it does not estimate overall application quality, usability, safety, user satisfaction, or marketing effectiveness. Nevertheless, it demonstrates that the principal one-target promotional interaction was implemented successfully on the test device. The failed multi-target condition identifies a concrete technical boundary that should guide future development.

TABLE II. FUNCTIONAL TEST SUMMARY

Scenario	Observed Output	Result
Camera access	Camera opens after permission is granted	Pass
Single marker detection	Assigned 3D model appears	Pass
Object interaction	Basic touch interaction works	Pass
Target revision / upload	Revised target accepted	Pass
Offline operation	AR works after installation	Pass
Perspective change	Model remains stable	Pass
Tested low light	Marker is detected	Pass
Multi target scan	Simultaneous detection and rendering of all target panels were not reliably achieved	Fail
3D model rendering	The 3D model assigned to the recognized target is rendered correctly	Pass
Model-target assignment verification	Each tested target triggers its intended 3D craft model	Pass

C. *Discussion*

The prototype demonstrates that marker-based AR can convert a printed promotional medium into a visual interaction point for local crafts. This result is consistent with broader AR work showing that digital overlays can add information and engagement to heritage-related content [5], [19]. In this case, the use of a physical poster is also practical because it gives the system a stable location for visual content and can be deployed in settings that already use printed promotion.

The main development lesson is that an AR promotional application depends on more than the 3D model. The image-target preparation was a critical technical element; an initially weak target required redesign before the prototype could be used reliably. The development process also benefited from limiting the catalog to four representative objects so that the project could focus on an end-to-end workflow, from documentation to Android build and functional test.

There are several limitations. First, the current AR application runs on Android only. Second, the test evidence is based on a small documented functional scenario set and does not include standardized usability instruments such as the System Usability Scale. Third, the project did not capture scanning time, frame rate, compatibility across device types, or results in outdoor exhibition conditions. Fourth, it did not test whether AR use improves product understanding, visitor engagement, purchase intention, or sales. Finally, multi-target tracking requires further optimization because the single-marker approach did not extend successfully to simultaneous recognition of several objects.

Future work should address these limitations through a larger user evaluation involving artisans, visitors, students, and prospective buyers. It should compare the AR poster with a conventional poster, measure task completion and scanning success under different lighting levels, test a broader range of devices, and add descriptive audio, product stories, and a web or online catalog connection. These extensions would make it possible to evaluate both technical robustness and promotional value.

IV. CONCLUSION

This study developed an Android marker-based AR promotional prototype for Selaawi bamboo crafts using the MDLC process. The system combines four representative 3D assets, Vuforia image targets, Unity integration, and a printed poster that provides both craft information and an AR trigger. The documented black-box test results show that the core single-target interaction functioned in the tested conditions, with nine of ten verification scenarios passing. The failed simultaneous multi-target scenario defines an important limitation. Overall, the prototype demonstrates that a marker-based AR workflow can extend a printed craft poster into an interactive visualization medium that supports localized craft storytelling and provides added cultural-economic value for bamboo artisans in Selaawi.

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