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LaSEEnem: Development and Quality Evaluation of a Museum Relic Recognition Application Using Convolutional Neural Networks

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ABSTRACT

Culture and heritage are important aspects of historical places like Vigan City, which is surrounded by museums to preserve and enliven the city's antiquity. In this study, the researchers investigated the difficulties that the museums of Vigan City encounter: traffic congestion and lengthy visitor lines, and the congested area that causes accidents and destroys the artifacts kept. Due to the conventional nature of the exhibition setup and the traditional communication style used for presenting the collections, museums had to keep their audiences engaged by closely examining innovative ways to employ technology to enhance their art collections. The researchers intended to develop LaSEEnem, a museum relic recognition application for selected museums of Vigan City. The researchers used descriptive and developmental designs to gather information needed to develop LaSEEnem. Furthermore, to develop the proposed application, the researchers used the Rapid Application Development (RAD) Model and the Convolutional Neural Network (CNN). The developed system was evaluated using the ISO 25010 evaluation tool. The results reflected a mean of 4.26, indicating that the system is Highly Acceptable as a digital tool intended to support artifact recognition and information access during museum visits. This study contributes to the growing body of research on AI-assisted cultural heritage applications by demonstrating the feasibility of integrating CNN-based image recognition with a mobile museum guide evaluated through the ISO 25010 quality model.

Keywords: *CNN, ISO 25010, LaSEEnem, Google Firebase, RAD*

INTRODUCTION

In the last few decades, technology has developed dramatically, impacting people's lives and enabling them to keep up. Beyond building seamless transportation infrastructure, such as roads, trains, and aircraft, technology has enabled people to communicate globally and lead fulfilling lives across different fields. In museology, a new paradigm has emerged through collaboration among specialists from other sectors, such as technology and museum administration.

From fewer and fewer contemplative sites, museums have become participatory environments that attract an increasing number of visitors (Wang & Li, 2021). People continuously flock to these destinations, and the struggle to navigate the crowd for a clear view can lead to adverse reactions (Jacobsen et al., 2019) and implications for tourist satisfaction (Koens et al., 2018).

Due to the conventional nature of the exhibition setup and the traditional communication style used for presenting the collections, regular visitors are restricted to merely viewing artifacts and admiring their aesthetic qualities (Pietroni et al., 2019) because people are frequently caught off guard and end up ruining spiritual symbolism as well as actual and intangible possessions (Wang et al., 2021).

Vigan City, being enlisted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as one of the Seven New Wonder Cities of the World, because of its spectacular tourist destinations, became the most visited places of the North (Tabunan, 2019; Chan, 2020) and increased the tourism industry of Ilocos Sur (Alconis & Aquino, 2019). However, the researchers observed that some of the tourist spots, like museums, had difficulties, especially on weekends and holidays, due to a large number of visitors, which can cause traffic and lengthy lines that visitors and residents alike encountered while trying to enjoy the artifacts kept at the museum (Alconis & Singun, 2019). In addition to spoiling the experience for visitors, the congested area increases the risk of mishaps such as unintentional bumping, scratches, or even breaks to the priceless artifacts on display.

Therefore, Slyiao and Papaioannou (2019) stated that museums must innovate new strategies to satisfy the changing needs of education and entertainment and adapt to sociocultural shifts. (SDG 4) In Liang et al. (2021), the rapid development of information technologies, including the Internet, social media, electronic platforms, and analytical tools, has significantly impacted the cultural and economic sphere of a city (Callejo & Singun, 2019).

To address the problem of inefficient museum visits, museums had to keep their audiences engaged by closely examining innovative ways to employ technology to enhance their art collections (Shehade, 2020; Welch, 2021). Images of cultural relics can be recognized and understood with the help of technologies such as the Internet, information and communication technologies, digital media technologies, interactive design theory, artificial intelligence, and image processing (Wallenburg,

2020) (SDG 9). This will attract the majority of visitors because the combination of culture and technology is currently a fundamental part of tourist destination strategies (Angelidou et al., 2017; Liu, 2022).

However, museum visitors may be challenged, as there must be greater internet connectivity, lower computer literacy, and access to necessary devices to make it easier for citizens to benefit from digital historical and cultural resources, unless this leads to unequal access to historical and cultural information and services (Schuster, 2017). Furthermore, using information technology requires storing vast volumes of personal data, which raises privacy and security concerns (Wu & Chen, 2022).

While previous studies have explored digital guides, virtual tours, and AI-based recognition systems for cultural heritage, little research has focused on developing and evaluating a lightweight, mobile relic-recognition application tailored to the operational constraints of local museums in the Philippines. In particular, there is a lack of empirical evidence on the quality and acceptability of CNN-based museum recognition systems evaluated using standardized software quality frameworks.

This study aligns with the Sustainable Development Goals by demonstrating how digital and AI-based tools can support cultural heritage initiatives and museum operations by improving information delivery. LaSEEnem is built to collaborate with the National Museum of the Philippines – Ilocos, comprising two museums: Padre Burgos House and the Old Carcel Museum (SDG 17). With emerging technologies, LaSEEnem is an innovative tool for identifying museum relics, providing users with a more efficient way to address the challenges posed by long lines. LaSEEnem aims to improve accessibility by providing digital images and text descriptions of selected artifacts. (SDG 16). The text descriptions can be effortlessly translated into other languages. In addition, by using a portable guide to navigate the museum, users may skip long talks and interviews. With its cutting-edge features, LaSEEnem is designed to support access to cultural information and artifact identification. (SDG 4), promotes AI innovation in cultural sectors (SDG 9), and preserves and digitizes cultural heritage (SDG 11), increases access to cultural information (SDG 16), and fosters collaboration between museums, tech firms, and cultural institutions (SDG 17).

Objectives of the Study

This study aimed to develop and evaluate LaSEEnem, a museum relic recognition application using a Convolutional Neural Network algorithm for selected museums in Vigan City. Specifically, it sought to: (1) Determine the existing

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guidelines and operational practices of the National Museum of the Philippines–Ilocos relevant to application development; (2) Identify the functional requirements of the LaSEEnem application based on stakeholder needs; (3) Develop the LaSEEnem application using a CNN-based image recognition model; and (4) Evaluate the acceptability of the developed application using the ISO 25010:2011 software quality model in terms of functional suitability, performance efficiency, usability, reliability, and security.

METHODOLOGY

Research Design. This study employed a descriptive and developmental design.

Participants of the Study. This study involved 15 users, a combination of foreign and local museum visitors, 5 museum officials, and 5 IT experts coming from different industries and institutions. The participants served as evaluators of system functionality and quality rather than as subjects of behavioral or learning intervention.

Research Instrument*.* The researchers conducted several interviews with the museum officials and observations of the museum operations to determine the guidelines and any substantial information that is beneficial to the development of the application. To develop the application, the researchers used RAD (Rapid Application Development Model), which comprises four phases:

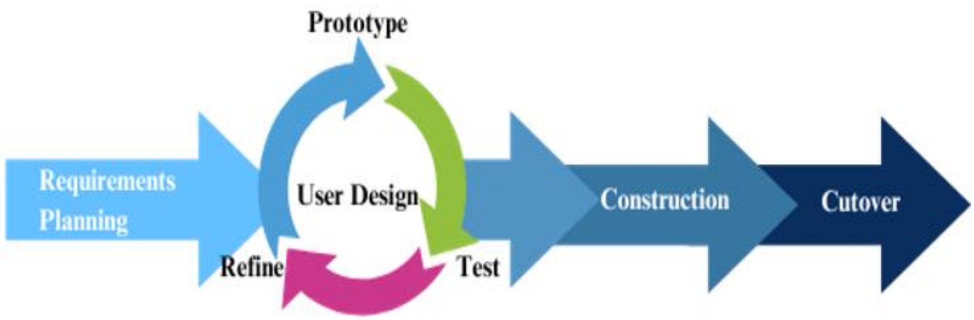

Figure 1. *Rapid Application Model*

Requirements Planning. The first phase in this model is Requirements Planning, in which the users and the project team identify the application's functionalities and features.

Iteration 1. The requirements planning process began with observations, document analysis, and interviews to ascertain stakeholders' needs and expectations, especially those of the National Museum of the Philippines staff and visitors. The researchers also planned for future problems that the program might encounter. After searching the internet, they chose the Convolutional Neural Network algorithm because they believe it to be more appropriate for classifying images. Since the application is for Android only, the researchers used the Integrated Development Environment Android Studio and the Java programming language to create its user interface. Because the codes were created in Google Colab, which favors Python as its first language, the application's backend models are implemented in Python.

Iteration 2. Museum staff expressed concern that the initial scope was too broad and might overwhelm visitors. They emphasized the need for a simple, intuitive application that focuses on artifact recognition and basic information display rather than on complex features. Based on the feedback, the researchers refined the requirements by limiting features to essential functionalities such as image capture, artifact identification, and concise informational output. Future risks, such as incorrect classifications and performance issues on low-end devices, were also identified and planned for during this iteration.

User Design. This is where much of the action takes place. Rather than following a set of specs, software developers rapidly produce designs with varying functionality and configurations. These designs are tested in real settings to demonstrate specific functionalities without a proper finish. It is natural, and the final product is generated only if the client and the researchers agree on it during the completion phase. The researchers drew numerous interface designs, experimenting with layouts, components, and functionality. Then, they showed the designs to the clients and asked them to identify what they liked and disliked. Through iterative design and testing, the researchers established a user-friendly interface supporting the intended users' satisfaction.

Iteration 1. The researchers created multiple low-fidelity interface designs, experimenting with layouts, navigation flow, and button placement. These designs were demonstrated to museum staff to gather early impressions without fully implementing the application. The stakeholders indicated that some layouts were visually cluttered and that text-heavy screens might distract visitors from the physical exhibits. They recommended larger buttons, minimal text, and clearer iconography.

Iteration 2. The researchers revised the interface designs by simplifying layouts, reducing on-screen text, and improving visual hierarchy. Interactive elements were made more prominent, and the overall design focused on ease of use and quick interaction.

Construction. At this phase, the beta versions from the design phase became a working application. The CNN algorithm is implemented in the development of the TensorFlow Lite model, which is used to deploy machine learning models to edge devices. To perform the CNN algorithm, the researchers prepared the necessary datasets for training. The dataset contains three sets for each class: the train, validation, and test. The train set consists of the images that need to be trained, the classification model learns the pattern and relationship of the data, and it contains 70% of the dataset for each class.

Input and Pre-processing.

All images were resized to 32 × 32 pixels with three color channels (RGB). Pixel values were normalized to the range [0, 1] using a rescaling factor of 1/255. The dataset was loaded using image_dataset_from_directory, with separate training, validation, and test sets. No data augmentation techniques (e.g., rotation, flipping, or scaling) were applied during training.

Network Architecture.

The CNN follows a sequential architecture consisting of three convolutional blocks and two fully connected layers. Each convolutional block contains a Conv2D layer with 32 filters and a 3 × 3 kernel, followed by a ReLU activation function and MaxPooling2D (2 × 2) for spatial downsampling. The extracted feature maps are flattened and passed to a dense layer with 128 neurons using ReLU activation. The final output layer contains six neurons, corresponding to the six target classes, and outputs raw logits for classification.

Training Configuration.

The model was trained for 30 epochs with a batch size of 20 using the Adam optimizer with a learning rate of 0.001. The Sparse Categorical Cross-Entropy loss function with logits (from_logits=True) was used. Model performance was monitored using validation accuracy, and the final trained model was exported to TensorFlow Lite for efficient on-device inference. The researchers also used Label-based Evaluation to determine the models' Accuracy, which measures how often a machine learning model correctly predicts the outcome; Precision, to determine the models' performance; and Recall, which measures how often the models correctly identify positive instances from all the actual positive samples in the dataset. The researchers began coding and testing the application to translate their conceptual design, interactive features, and basic functionality into a physical interactive application. These are repeated until a final result is achieved that meets the stakeholders' expectations and objectives.

Iteration 1. The first construction iteration involved transforming approved designs into a functional beta application. Core features, including image capture, CNN-based classification, and basic result display, were coded and tested. Initial versions of the TensorFlow Lite model were integrated into the application. The stakeholders observed occasional delays in image recognition and noted that misclassifications could confuse visitors. They suggested improving performance and adding clearer explanations of results.

Iteration 2. The researchers optimized the CNN model, refined the dataset quality, and improved error handling within the application. Classification results were presented more clearly, and performance testing was repeated to ensure smoother recognition. The perfect accuracy, precision, and recall values were obtained under controlled dataset conditions and should be interpreted as indicative of model performance within the trained classes rather than as real-world deployment accuracy.

Cutover. The client finalized the software's requirements, operations, layout, and interface at this phase. The researchers successfully developed the application, which is ready to use in a real setting. Moreover, to evaluate the developed application, the researchers used the ISO 25010 evaluation tool as their instrument to assess its acceptability to function and be implemented in a real-world setting.

Iteration 1. During the first cutover iteration, the application was installed and configured for real-world use. Final checks were conducted on functionality, layout, and system stability. Minor bugs were identified during actual testing within the museum environment.

Iteration 2. The researchers addressed these concerns by adding brief on-screen instructions and further tuning the CNN model to handle varying lighting scenarios. The researchers also ensured that LaSEEnem is installed correctly and configured to help their stakeholders use the application effectively. They also continued looking for faults and bugs that needed to be fixed.

Data Gathering Procedures. The researchers began gathering just after obtaining permission from the authorities, and then they began interviewing the museum officials about the museum's established guidelines and booking policies. The

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researchers further investigated the museum's operations and visitors' experience through numerous observations at different times (morning, afternoon, weekdays, weekends). They used data from the interview and observation to determine the possible features of the application based on the observed needs of the officials and visitors, while still aligning with the museum's guidelines and policies.

Data Analysis. The data collected from this study are rigorously analyzed by computing the total mean, then determining the descriptive rating using the Likert Scale Rating, and interpreting the acceptability rate of the application using the scale of level of acceptability test result interpretation.

Point	Descriptive Rating
1	Excellent
2	Very Satisfactory
3	Satisfactory
4	Needs Improvement
5	Poor

Point	Range	Descriptive Rating	Descriptive Interpretation
5	4.30-5.00	Excellent	Very Highly Acceptable
4	3.50-4.29	Very Satisfactory	Highly Acceptable
3	2.70-3.49	Satisfactory	Acceptable
2	1.90-2.69	Needs Improvement	Fairly Acceptable
1	1.00-1.89	Poor	Not Acceptable

RESULTS AND DISCUSSION

This part presents, analyzes, and interprets the study's findings on the development of LaSEEnem: A Museum Relic Recognition Application for the National Museum of the Philippines-Ilocos.

1. Determine the guidelines and procedures of the National Museum of the Philippines-Ilocos

The National Museum of the Philippines - Ilocos upholds strict rules to protect its exhibits and ensure a safe, respectful experience for visitors. It is accessible to everyone, including individuals with disabilities, though wheelchair access is limited in some areas. Groups of 20 or more must book in advance, and visitor limits are enforced in certain galleries to preserve wooden floors.

Prohibited items include food, drinks, large bags, tripods, and umbrellas, which may damage artifacts. Flash photography, smoking, touching exhibits, and pens are banned to protect delicate relics. Personal photography is allowed but must remain respectful, while commercial photography requires prior approval. Security inspections are mandatory, and wrapped packages are prohibited for safety reasons.

Aligning system functionalities with existing museum guidelines ensures that the application complements, rather than disrupts, established museum operations. With its focus on preservation and visitor safety, the museum maintains a well-organized and dignified environment, ensuring a valuable experience for the community.

2. Determine the Functional Requirements

Table 1 presents the functional requirements gathered from the interview and observations.

Table 1
Functional Requirements

Functional Requirements	Description
Login/Register	Users need to first register to create an account, then log in to access the Dashboard.
Fact Box	Users can randomly read bite-sized facts about Vigan.
Scan Button	Users can click the Scan button to start scanning images in the museum and display their descriptions.
Museum List	Users are required to choose which museum they are in so that the application can set which dataset will be used to scan relics.
History	Users can view the History and Timeline of Vigan City, as well as the application’s information and the museum.
Tutorial	Users can access an interactive tutorial when first downloading it and can still learn more in the Help Section.
Profile	Users can view their Profile and update their username and photo.
Likes	Users are able to add the relics as Likes to keep them pinned and delete them.

Selection of Language Translation	Users can select the translation of the scanned objects' descriptions.
Audio	Users can listen to the audio description in different ways to learn the proper pronunciation of the object.
Customer Satisfaction Feedback	Users can send their feedback to the museum operators or to the museum.
Log Out	Users can log out of their accounts to ensure their security.

The functional requirements of the LaSEEnem application were developed in alignment with the study's objectives to support the needs of the National Museum of the Philippines (NMP)–Ilocos and its visitors. Existing museum practices, such as guided tours, static exhibits, and feedback collection, are reflected in features like the History module, Museum List, and Customer Satisfaction Feedback, which digitize and enhance current information delivery and evaluation methods.

All identified functionalities collectively define the system requirements of LaSEEnem, including user account management, information access, personalization, and interactive learning features. The application's development using a Convolutional Neural Network (CNN) algorithm is primarily supported by the Scan Button and Museum List, which enable image recognition of museum relics using appropriate datasets. Supporting features such as language translation and audio descriptions enhance accessibility and comprehension of recognized objects, while additional modules promote user engagement and learning.

Furthermore, integrating these functional requirements ensures that the application can be evaluated using the ISO 25010:2011 quality model. Security and reliability are addressed through authentication features, functional suitability and performance efficiency through scanning and dataset selection, and usability through tutorials, informational modules, and feedback mechanisms. Aligning system functionalities with existing museum guidelines ensures that the application complements, rather than disrupts, established museum operations.

3. Development of the LaSEEnem Application Using CNN

Table 2 presents the summary of label-based evaluation of old carcel museum and padre burgos house classification model.

Table 2

Summary of Label-Based Evaluation of Old Carcel Museum and Padre Burgos House Classification Model

		Old Carcel Museum	Padre Burgos House
Accuracy	Total Correct Predictions	143	58
	Total Predictions	143	58
	Sub Total	**1.0**	**1.0**
Precision	Total True Positive	143	58
	Total False Positive	0	0
	Sub Total	**1.0**	**1.0**
Recall	Total True Positive	143	58
	Total False Negative	0	0
	Sub Total	**1.0**	**1.0**
	Total Percentage	**100%**	**100%**

On Accuracy, Old Carcel Museum garnered a perfect score of 143 correct predictions out of 143 total predictions, while Padre Burgos House also got 58 correct predictions out of 58 total predictions. On Precision, the Old Carcel Museum has 143 total true positives, while the Padre Burgos House has 58. Both models have zero (0) false positives. On Recall, Old Carcel Museum has 143 true positives, while Padre Burgos House has 58. Both models have zero (0) false negatives. This results in both models demonstrated high classification performance within the defined dataset and target classes.

4. Evaluation of Quality of the Application

The acceptability ratings reflect perceived system quality and usability rather than learning outcomes, visitor satisfaction, or behavioral change.

Table 4.

Summary of the Evaluation of the Developed LaSEEnem Application

Criteria	Mean	Descriptive Rating	Acceptability Rating
Functionality Suitability	4.52	Excellent	Very Highly Acceptable
Performance Efficiency	4.13	Very Satisfactory	Highly Acceptable
Usability	4.31	Excellent	Very Highly Acceptable

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Reliability	4.17	Very Satisfactory	Highly Acceptable
Security	4.16	Very Satisfactory	Highly Acceptable
Total	**4.26**	**Very Satisfactory**	**Highly Acceptable**

On Functional Suitability, the application was rated descriptively as "Excellent" and has an acceptability rating of "Very Highly Acceptable" with a mean of 4.52. On Performance Efficiency, the application was rated descriptively as "Very Satisfactory" and has an acceptability rating of "Highly Acceptable" with a mean of 4.13. On Usability, the app was rated "Excellent" and has an acceptability rating of "Very Highly Acceptable," with a mean of 4.3. On Reliability, the application was rated descriptively as "Very Satisfactory" and has an acceptability rating of "Highly Acceptable" with a mean of 4.17. On Security, the application was rated descriptively as "Very Satisfactory" and has an acceptability rating of "Highly Acceptable" with a mean of 4.16. Overall, the application was rated descriptively as "Very Satisfactory," with a mean of 4.26 and an acceptability rate of "Highly Acceptable."

CONCLUSIONS

The researchers developed a museum information system application to address selected limitations of traditional relic information delivery through digital support, in which visitors were required to manually log in, seek assistance from museum personnel, and approach small placards to read information, which could be difficult when crowded and could lead to accidental damage of fragile artifacts. The core technology employed in this application is the Convolutional Neural Network (CNN) algorithm, which was specifically chosen for its capacity to automatically recognize and extract complex features from raw image data. The application's functional requirements include user login and registration, a scanning button, a fact box, history tracking, an interactive tutorial, language translation support, and audio support. The CNN model proved highly effective, as indicated by the Confusion Matrices, which show no False Positives (FP) or False Negatives (FN). Consequently, the model achieved perfect 1.0 (100%) evaluations for Accuracy, Precision, and Recall, demonstrating successful technical integration of the CNN model within the application and well-trained datasets. The software's acceptability was rigorously assessed using the ISO 25010 standard, yielding impressive results: the application was rated with a mean of 4.26, descriptively rated as Excellent with an acceptability rating of Very High Acceptability. Overall, the study establishes the technical feasibility and quality acceptability of LaSEEnem as a prototype museum relic recognition application.

RECOMMENDATIONS

The researchers provided several key recommendations to enhance the LaSEEnem system and encourage broader adoption of technology in museum practices. Strategically, the researchers recommend that museums incorporate technology into their operations to streamline their work and support the exploration of digital tools appropriate to their operational context. Focusing on the application's interface and functionality, the researchers noted that while the existing user interface is clean and minimalistic, improvements should be made by adding animation and enhancing the layout of elements. To further boost stakeholder interest and provide a more interactive experience beyond the current functionality (which is limited to basic needs), they propose adding advanced features, such as 3D models of the relics or a virtual museum tour. From a technical standpoint, the researchers confirmed the suitability of the CNN algorithm for developing LaSEEnem and advised continuing efforts to collect, preprocess, implement, and evaluate a comprehensive dataset to maximize its utilization. To maintain the application's relevance as museum collections, grow, it is recommended that an admin portal be developed to enable real-time updates to the dataset. Lastly, to accommodate a wider variety of users, the researchers recommend expanding the application, currently available only on Android devices, to iOS to increase stakeholder diversity. Future studies may examine user engagement, learning outcomes, and long-term adoption of LaSEEnem in operational museum settings.

ETHICAL STATEMENT

In accordance with the Data Privacy Act of 2012, the study was reviewed and approved by the Ethics Review Committee of Central Luzon State University and recorded in the database under ERC Code ***2023-808***. Accordingly, the researchers prioritized voluntary participation when recruiting research participants. Hence, each participant and their guardian have the right to decide whether to participate or decline the researchers' invitation. Additionally, they are informed of their right to withdraw from the study at any point if they feel uncomfortable after participating in the researchers' data collection. The researchers guarantee that each respondent's rights to anonymity and privacy are protected at all costs. Rest assured that all data collected from the participants are treated with the utmost confidentiality and used solely for the purpose of the study, as agreed by the participants and the researchers.

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