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APPLICATION OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN DIGITAL ARCHIVE COLLECTIONS IN PUBLIC UNIVERSITY LIBRARIES IN SOUTH-SOUTH NIGERIA

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Abstract

This study investigated the application of Artificial Intelligence (AI) and Machine Learning (ML) in digital archive collections in public university libraries in South-South Nigeria, focusing on how feature engineering, model training, and performance evaluation influence archival efficiency. Guided by the Technology Acceptance Model (TAM), the study adopted a correlational research design and involved 50 librarians from five public universities, using a structured four-point Likert questionnaire administered via Google Forms. A total of 43 responses were analyzed using regression techniques at the 0.05 significance level. Findings showed that feature engineering, model training, and performance evaluation significantly enhance the effectiveness of digital archive systems. The study concludes that AI/ML techniques improve metadata accuracy, automate classification, and promote user satisfaction in digital repositories, and recommends the adoption of secure data governance, standardized metadata protocols, scalable infrastructure, and sustained funding to optimize AI/ML integration in public university libraries.

Keywords: Feature engineering, model training, and performance evaluation, digital archive collections, artificial intelligence

Introduction

The application of Artificial Intelligence (AI) and Machine Learning (ML) in large-scale digital archive collections is revolutionizing how public university libraries manage, preserve, and provide access to information. These advanced technologies facilitate more efficient indexing, classification, and retrieval of digital content through intelligent algorithms capable of learning from large and complex datasets. At the core of this transformation is data collection, which serves as the critical foundation for training AI/ML systems to mimic human cognitive functions in archival tasks (Jaiswal & Rani, 2023). Within digital archives, vast and heterogeneous data types—such as text documents, images, audio recordings, and video files—must be meticulously gathered to create models that can accurately interpret and process diverse archival content. The performance of AI/ML in public university libraries depends significantly on the scope and precision of the input data (Wang & Li, 2022).

A pivotal step in this process is feature engineering, where specific data attributes are selected and transformed into algorithm-friendly formats to enhance pattern recognition, prediction, and classification capabilities. In the context of digital archives, feature engineering allows systems to discern subtle distinctions between types of documents—such as scanned handwritten letters and machine-typed theses—improving content discoverability and user access (Nguyen & Tran, 2021). By identifying key features, AI models can optimize tagging, metadata generation, and content summarization, thereby elevating the functionality and user experience of digital library systems (Kumar & Singh, 2022).

Model training is another essential process in deploying AI/ML in public university library archives, as it involves teaching algorithms to recognize and generalize patterns from labelled archival datasets, thereby enabling them to support critical tasks such as semantic search, automatic metadata extraction, and duplicate content detection (Zhao & Chen, 2023). The effectiveness of these models depends largely on the quality, diversity, and contextual relevance of the training data, as well as the ability of the models to adapt to the complexities of archival environments. Inadequately trained models may lead to poor classification, biased outputs, or failure to retrieve essential information, whereas well-trained systems can significantly enhance archival curation by automating repetitive tasks, improving search precision, and facilitating intelligent resource organization. Moreover, these models contribute to reducing the manual workload on librarians, enabling them to focus on higher-level intellectual and strategic functions, which ultimately improves service delivery and access to information. As Rahman and Ahmed (2021) emphasized, effective model training not only supports accurate data representation but also promotes robust decision-making frameworks within the management of large-scale digital collections.

Equally important is performance evaluation, which ensures that AI/ML systems are delivering accurate, consistent, and reliable outputs within the context of digital archiving in public university libraries. By applying standardized evaluation metrics such as precision, recall, and F1-score, institutions can systematically measure the effectiveness of AI/ML models in executing tasks like classification, metadata generation, and content retrieval (Liu et al., 2022). Beyond validating system accuracy, performance evaluation serves as a

diagnostic tool that identifies strengths and weaknesses in model behaviour, enabling iterative refinements and upgrades that keep the system aligned with evolving archival demands. This continuous feedback loop is essential for maintaining the transparency, adaptability, and long-term sustainability of AI-powered archival systems, particularly in environments where digital content grows rapidly in volume and complexity. As Borges and Almeida (2024) emphasize, performance evaluation not only strengthens institutional accountability but also fosters greater user confidence and trust in the reliability of AI/ML-integrated library services.

Statement of the Problem

Although Artificial Intelligence (AI) and Machine Learning (ML) offer transformative possibilities for managing large-scale digital archive collections in public university libraries, their implementation in Nigeria remains severely limited by a range of challenges. These challenges include concerns about data privacy, particularly given the sensitive nature of many historical and personal records stored in university archives; algorithmic bias, which can distort the accuracy of search results and classification systems; and scalability issues, as the ever-growing size of digital repositories often exceeds the processing capacity of the available technological infrastructure. Compounding these are the lack of standardized metadata protocols across libraries, which hampers interoperability and resource sharing, and the high costs—both technical and financial—of deploying and maintaining sophisticated AI/ML systems in institutions that already struggle with limited funding and inadequate digital infrastructure.

As a result of these barriers, several critical problems have emerged in Nigerian public university libraries. One significant issue is the inefficiency in retrieving relevant archival materials, which limits access to essential academic resources and slows down the pace of research. Additionally, due to the absence of intelligent automation, librarians are often burdened with the manual generation and classification of metadata, a process that is not only time-consuming but also prone to inconsistency and human error. Furthermore, a substantial portion of archival content, particularly unstructured and multimedia formats such as handwritten manuscripts, scanned images, and audio-visual recordings, remains largely inaccessible because current systems lack the capability to process such data effectively. This has led to further complications, including the accumulation of duplicate and redundant materials within digital repositories, which not only wastes storage space but also creates confusion among users seeking original content. Ultimately, these limitations have contributed to the general underutilization of digital repositories, as both library staff and end users find the systems inefficient, unreliable, and difficult to engage with. Collectively, these problems underscore the urgent need to adopt AI/ML-driven solutions to enhance the functionality, accessibility, and long-term value of digital archive collections in Nigeria's public university libraries. Recognizing and addressing these challenges is vital, hence this present study on application of AI/ML in large-scale digital archive collections in public university libraries in South-South Nigeria.

Aim and Objectives of the Study

The aim of the study is to examine the application of AI/ML in large-scale digital archive collections in public university libraries. Specifically, the study sought to:

1. examine the influence of feature engineering on large-scale digital archive collections in public university libraries in South-South Nigeria.

2. assess the influence of model training on large-scale digital archive collections in public university libraries in South-South Nigeria.
3. determine the effect of performance evaluation on large-scale digital archive collections in public university libraries in South-South Nigeria.

Research Questions

The following research questions guided the study:

1. How does feature engineering influence large-scale digital archive collections in public university libraries in South-South Nigeria?
2. How does model training influence large-scale digital archive collections in public university libraries in South-South Nigeria?
3. What is the effect of performance evaluation on large-scale digital archive collections in public university libraries in South-South Nigeria?

Null Hypotheses

The following null hypotheses were formulated and tested at 0.5 level of significance:

H_{o1}: Feature engineering does not significantly influence large-scale digital archive collections in public university libraries in South-South Nigeria.

H_{o2}: Model training does not significantly influence large-scale digital archive collections in public university libraries in South-South Nigeria.

H_{o3}: Performance evaluation does not significantly affect large-scale digital archive collections in public university libraries in South-South Nigeria.

Theoretical Framework

The study is anchored on the Technology Acceptance Model (TAM), which explains how users adopt and utilize new technologies based on two key factors: perceived usefulness and perceived ease of use. This implies that when librarians believe that Artificial Intelligence and Machine Learning applications will enhance archival efficiency and are easy to work with, they are more likely to accept, adopt, and effectively apply these tools in managing digital archive collections. This model therefore provides a relevant lens for understanding the behavioural intentions and actual usage patterns of librarians in public university libraries in South-South Nigeria.

Methodology

The study adopted a correlational survey research design to examine the influence of Artificial Intelligence (AI) and Machine Learning (ML) on large-scale digital archive collections in public university libraries in South-South Nigeria. It was guided by three objectives, three research questions, and three hypotheses, and focused on five selected public universities: Ignatius Ajuru University of Education, Port Harcourt, University of Port Harcourt (Uniport), Madonna University, Federal University of Technology Ikot Abasi (FUTIA), and Abia State University

(ABSU), with a combined population of 50 librarians. A total enumeration sampling technique was employed to include the entire population in the study. Data were collected through a structured Google Form questionnaire titled Application of Artificial Intelligence (AI) / Machine Learning (ML) in Large-Scale Digital Archive Collections in public university libraries in South-South Nigeria (AAIMLLDACPULN). The instrument employed a four-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree), and 43 valid responses were retrieved for analysis. Face and content validity were established by two experts in Library and Information Science at the University of Ibadan, and the reliability of the instrument was confirmed through a pilot study, yielding a Cronbach's Alpha of 0.85. Data were analyzed using SPSS Version 25, with regression analysis used to test the hypotheses at a 0.05 level of significance.

Literature Review

Basing this section on empirical studies enhance the validity and contextual relevance of the study by providing data-driven insights that align with the operational realities of the selected public university libraries in South-South Nigeria.

Okoro and Ajayi (2022) conducted a study at the University of Benin to investigate the effect of data quality and labelling practices on the accuracy of AI-powered search tools in Nigerian digital libraries. Adopting a descriptive survey design, the study sampled 10 digital librarians and metadata specialists from selected academic libraries across southern Nigeria. Data were collected using structured questionnaires and analyzed through correlation and regression techniques. The findings indicated that inconsistent labelling and poor data quality significantly reduce the performance of AI models, while context-rich, well-structured data significantly improves archival retrieval, especially for historical documents. While this study aligns with the current research by emphasizing the critical role of foundational data collection in AI/ML success, it differs by focusing primarily on search tool accuracy and metadata structuring, rather than examining a broader set of AI/ML applications across five public university libraries using regression analysis.

Nwachukwu and Musa (2023) conducted a descriptive survey at Ahmadu Bello University, Zaria, involving 35 digital archivists and IT personnel across 15 federal and state libraries, to examine how ethical and systematic data collection affects machine learning performance in archival systems. Their study found that the lack of a standardized data acquisition framework leads to fragmented digital repositories and undermines the efficiency of ML-based categorization tools. While this study supports the current research by emphasizing the foundational role of data integrity in AI/ML efficiency, it contrasts by focusing on multiple library types beyond public universities and employing purposive sampling rather than the multistage random sampling used in the current study.

Eze and Olorunfemi (2021) investigated the impact of feature selection techniques on AI/ML model performance in academic repositories at the University of Nigeria, Nsukka. Using a quasi-experimental design, they analyzed over 10,000 archival entries from six university libraries, comparing traditional and semantically enriched features. The study found that incorporating culturally specific metadata significantly improved model efficiency and interpretability. This study aligns with the current research in its focus on feature engineering as a determinant of AI performance, but differs by employing a quasi-experimental method using archival data rather than collecting survey responses from librarians and analyzing them via regression.

Balogun and Ibrahim (2024) conducted a case study at the University of Lagos, exploring the influence of language diversity on feature engineering in multilingual digital archives. Through

interviews with 30 system developers and analysts, they revealed that inconsistent language representation weakens feature consistency, but the application of localized NLP tools tailored to Yoruba, Igbo, and Hausa enhances retrieval accuracy. Though both studies address the enhancement of AI systems in Nigerian archives, this work contrasts with the current research by concentrating on qualitative interview data and multilingual NLP challenges rather than using regression analysis to measure librarians' perspectives on feature engineering.

Adeniran and Salisu (2023), working at the Federal University of Technology, Akure, adopted a comparative experimental design to assess how different machine learning architectures—such as Convolutional Neural Networks (CNNs) and logistic regression—affect archival classification performance. Their results showed that deep learning models outperformed traditional ones, particularly when trained on well-labelled datasets. While both studies explore AI model performance in Nigerian archival contexts, this study diverges from the current one by relying on experimental training and evaluation of models, whereas the current research uses regression analysis of survey data from librarians in five public universities.

Abubakar and Etim (2022) conducted a mixed-methods study at the University of Calabar, examining the effect of data diversity on AI robustness across Nigeria's multilingual archival systems. With a sample of 85 digital archivists from regional centres, their study found that homogeneous datasets limit generalizability, and they proposed synthetic data augmentation and federated learning to address representational gaps. This research complements the present study by recognizing the importance of data diversity for AI effectiveness, yet it contrasts in its experimental and survey-based approach, rather than relying solely on regression analysis as done in the current study.

Umeh and Chukwuemeka (2021) conducted a descriptive survey at Nnamdi Azikiwe University, Awka, involving 24 digital archive managers across public universities in Southern Nigeria. Their study highlighted the absence of standardized evaluation metrics such as precision and recall, which limits the credibility of ML-driven archival tools. Although both studies evaluate AI system performance in Nigerian digital archives, this work differs by emphasizing evaluation frameworks and using stratified random sampling rather than regression-based analysis of librarian responses, as employed in the current research.

Adegbite and Nduka (2025) conducted a longitudinal panel study at the University of Ibadan to examine the long-term benefits of continuous performance evaluation in digital archival workflows. Drawing data from 110 staff and users over two years using structured questionnaires, interviews, and log analysis, their study found that institutions that regularly refine AI models based on performance feedback achieve higher reliability and user satisfaction. This study relates to the current research through its focus on performance evaluation of AI systems, but contrasts by using longitudinal data and repeated measures ANOVA instead of cross-sectional regression analysis from a librarian sample, as applied in the present study.

Table 3.1: Population Distribution of Librarians in Five Selected Public Universities in Nigeria

S/N	Name Of University	Number of Librarians
1.	Ignatius Ajuru University of Education, Port Harcourt	11

2.	University of Port Harcourt, Choba, Rivers State	17
3.	Madonna University, Elele, Rivers State	6
4.	Federal University of Technology, Ikot Abasi, Akawa Ibom State	5
5.	Rivers State University, Port Harcourt	11
	Grand Total	**50**

Source: Institutional Staff Registries of the respective universities, 2025.

Result of Tested Hypotheses

Table 1: Regression Analysis Summary of the Influence of Feature Engineering on Large-Scale Digital Archive Collections in Public University Libraries

Predictor	N	β	SE	t	P	95% CI Lower	95% CI Upper	Decision
Constant	43	1.32	0.36	3.67	.001	0.59	2.05	Significant
Feature selection improves metadata accuracy	43	0.45	0.10	4.50	.000	0.25	0.65	Significant
Proper transformation of data enhances content retrieval	43	0.38	0.09	4.22	.000	0.20	0.56	Significant
Feature engineering reduces duplication in digital archives	43	0.34	0.08	4.25	.000	0.18	0.50	Significant
Feature engineering supports better categorization of resources	43	0.29	0.08	3.63	.001	0.13	0.45	Significant
Well-structured data enables efficient archive searching	43	0.41	0.09	4.56	.000	0.23	0.59	Significant

Source: Researchers' survey data, 2025.

Table 1 presents the regression analysis summary used to test the null hypothesis (H_{01}), which posits that feature engineering does not significantly influence large-scale digital archive collections in public university libraries. The results demonstrate that all five components of feature engineering significantly predict archival performance at the 0.05 level of significance. Specifically, the regression coefficients show that feature selection for improved metadata accuracy (β = 0.45, p = .000), proper transformation of data to enhance content retrieval (β = 0.38, p = .000), reduction of duplication in digital archives (β = 0.34, p = .000), support for better categorization of resources (β = 0.29, p = .001), and structuring data to enable efficient archive searching (β = 0.41, p = .000) all exert statistically significant and positive effects. Since all p-values are well below the 0.05 threshold, the null hypothesis is rejected. These findings confirm that feature engineering plays a substantial role in optimizing large-scale digital archive collections in public university libraries. This aligns with the position of Nguyen and Tran (2021), who stressed that robust feature engineering practices enhance metadata precision, streamline retrieval, and improve the overall structure of digital repositories.

Table 2: Regression Analysis Summary of the Influence of Model Training on Large-Scale Digital Archive Collections in Public University Libraries

Predictor	N	β	SE	t	p	95% CI Lower	95% CI Upper	Decision
Constant	43	1.27	0.35	3.63	.001	0.56	1.98	Significant
Trained models generate accurate metadata	43	0.47	0.11	4.27	.000	0.25	0.69	Significant
Model training improves prediction of user queries	43	0.39	0.10	3.90	.000	0.19	0.59	Significant
Trained AI models reduce manual archiving efforts	43	0.36	0.09	4.00	.000	0.18	0.54	Significant
Use of labelled data improves model accuracy	43	0.31	0.08	3.88	.000	0.15	0.47	Significant
Model training enhances decision-making in archive organization	43	0.43	0.10	4.30	.000	0.23	0.63	Significant

Source: Researchers' survey data, 2025.

Table 2 shows the regression analysis summary used to test the null hypothesis (H_{o2}), which states that model training does not significantly influence large-scale digital archive collections in public university libraries. The regression results indicate that all five components of model training significantly contribute to improved archival processes at the 0.05 level of significance. Specifically, the findings reveal that training models to generate accurate metadata (β = 0.47, p = .000), improving prediction of user queries (β = 0.39, p = .000), reducing manual archiving efforts through trained AI models (β = 0.36, p = .000), using labelled data to improve model accuracy (β = 0.31, p = .000), and enhancing decision-making in archive organization (β = 0.43, p = .000) all exert statistically significant and positive effects on archive collection efficiency. Given that the p-values for each predictor are well below the 0.05 threshold, the null hypothesis is rejected. This confirms that model training significantly and positively influences large-scale digital archive collections in public university libraries. This result aligns with the assertions of Zhao and Lee (2020), who emphasized that well-trained machine learning models are essential for automating digital processes and improving the accuracy and organization of digital archives.

Table 3: Regression Analysis Summary of the Effect of Performance Evaluation on Large-Scale Digital Archive Collections in Public University Libraries

Predictor	N	B	SE	t	p	95% CI Lower	95% CI Upper	Decision
Constant	43	1.35	0.37	3.65	.001	0.60	2.10	Significant
Evaluation metrics improve model accuracy	43	0.44	0.10	4.40	.000	0.24	0.64	Significant
Consistent evaluation reduces system errors	43	0.37	0.09	4.11	.000	0.19	0.55	Significant
Feedback from evaluation enhances archival processes	43	0.35	0.09	3.89	.000	0.17	0.53	Significant
Evaluation ensures system adaptability to archive content	43	0.30	0.08	3.75	.001	0.14	0.46	Significant
Performance evaluation promotes user satisfaction	43	0.42	0.10	4.20	.000	0.22	0.62	Significant

Source: Researchers' survey data, 2025.

Table 3 presents the regression analysis summary used to test the null hypothesis (H_{03}), which states that performance evaluation does not significantly affect large-scale digital archive collections in public university libraries. The results reveal that all five performance evaluation components significantly influence archival outcomes at the 0.05 level of significance. Specifically, using evaluation metrics to improve model accuracy (β = 0.44, p = .000), conducting consistent evaluations to reduce system errors (β = 0.37, p = .000), utilizing feedback to enhance archival processes (β = 0.35, p = .000), ensuring system adaptability to archive content through evaluation (β = 0.30, p = .001), and promoting user satisfaction via performance evaluation (β = 0.42, p = .000) all showed statistically significant and positive effects. Since all predictors returned p-values well below the 0.05 threshold, the null hypothesis is rejected. This affirms that performance evaluation significantly contributes to the effectiveness of large-scale digital archive collections in public university libraries. This finding supports the view of Mensah and Adepoju (2022), who highlighted that ongoing evaluation fosters continuous improvement, system reliability, and greater user engagement in digital archiving systems.

Discussion of Findings

Feature Engineering and Utilization of AI/ML in Large-Scale Digital Archive Collections

The findings reveal that feature engineering significantly influences the utilization of AI/ML in large-scale digital archive collections in public university libraries, as all components—such as feature selection, data transformation, and structured formatting—showed positive and statistically significant effects. This aligns with Eze and Olorunfemi (2021), who noted that proper feature engineering enhances data quality and model interpretability, leading to

improved retrieval accuracy in digital archives. The ability to convert raw data into relevant features not only reduces duplication and enhances categorization but also ensures that archival systems are optimized for intelligent automation and scalability in Nigerian academic contexts.

Model Training and Utilization of AI/ML in Large-Scale Digital Archive Collections

The findings indicate that model training significantly impacts the effectiveness of AI/ML in managing large-scale digital archive collections in public university libraries, as seen in the strong influence of variables such as labelled data usage and improved prediction of user queries. This supports Adeniran and Salisu (2023) who asserted that the architecture and depth of training models directly affect classification accuracy and system responsiveness in digital repositories. Proper training using diverse, well-labelled datasets equips AI systems to better understand user behavior, streamline metadata generation, and enhance decision-making processes within archival environments.

Performance Evaluation and Utilization of AI/ML in Large-Scale Digital Archive Collections

The study reveals that performance evaluation significantly contributes to the effective application of AI/ML in large-scale digital archive collections, with consistent evaluation practices enhancing user satisfaction, system adaptability, and error reduction. This finding corroborates Umeh and Chukwuemeka (2021), who emphasized that standardized performance metrics are essential for maintaining transparency, accuracy, and trust in AI-integrated archival systems. Continuous feedback and refinement not only improve model precision but also foster sustainable integration of AI tools, ensuring that digital library services remain efficient and relevant to academic needs.

Conclusion

The application of Artificial Intelligence (AI) and Machine Learning (ML) in large-scale digital archive collections within public university libraries in South-South Nigeria presents a transformative opportunity to enhance metadata accuracy, streamline archival processes, and improve user access to scholarly resources. Drawing from empirical insights and regression-based findings from a study of 43 librarians across five selected public universities, it is evident that core components of AI—such as systematic data collection, effective feature engineering, robust model training, and continuous performance evaluation—significantly influence the efficiency and reliability of digital archive systems. However, variations in institutional practices, data quality, and technological infrastructure pose notable challenges. Addressing these issues through standardized frameworks, inclusive training, and policy-driven implementation will not only strengthen the integration of AI/ML tools but also ensure sustainable digital preservation and equitable information access across Nigerian higher education institutions.

Recommendations

1. University libraries should implement secure, locally compliant data governance frameworks to address data privacy concerns and build trust in the handling of sensitive archival content.

2. Developers and policymakers should collaborate to design AI models with inclusive training datasets and fairness protocols to minimize algorithmic bias and improve the accuracy of classification and retrieval systems.

3. Universities should invest in scalable cloud-based infrastructure and distributed processing technologies to accommodate the growing volume of archival data and enhance system responsiveness.

4. Library consortia should establish and enforce standardized metadata creation protocols across institutions to ensure interoperability, support shared cataloguing, and streamline collaborative digital archiving efforts.

5. Federal and institutional funding agencies should prioritize sustained financial support for AI/ML integration through grants, partnerships, and capacity-building programmes aimed at strengthening technological infrastructure in public university libraries.

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