A Service-Oriented Architecture-Based Electronic Library (E-Library) System

[1]Oni, Olujimi O, [2]Aderanti Aderemi T, and [3]Osifade, Muyiwa S
[1]Department of Computer Science, Gateway ICT Polytechnic, Saapade
[2]Department of Computer Engineering Technology, Gateway ICT Polytechnic, Saapade
[3]Department of Library and Information Science, Gateway ICT Polytechnic, Saapade
Corresponding Author: oniolujimi@gmail.com; Call: 08025038398; 08062618986

Abstract

Libraries in the digital age are changing dramatically from static physical spaces to dynamic electronic information power houses. This demands the development of sophisticated electronic library (e-library) systems that can meet up with today's digital experience. However, the design of such systems remains daunting task, particularly as scalability, interoperability, and adaptability issues are still plaguing the traditional e-library systems. To tackle these challenges, this study proposed an e-library system built on Service-Oriented Architecture (SOA) principles of loose coupling, reusability, interoperability and discoverability among others to effectively manage and grant access to enormous amounts of digital resources. The architecture incorporates several services, including content management, search, retrieval, and user administration to provide a unified, scalable system that can adjust to changing customer needs and technology breakthroughs. After implantation of the developed e-library system, it was tested and validated using randomly selected students. Results obtained showed that it was significantly more flexible, scalable, and interoperable than previous systems. The results indicate that SOA offers improved performance and user satisfaction as a workable alternative for contemporary e-library systems. Finally, the study offers recommendations for future work, such as incorporating cutting-edge technology like cloud computing, AI, and machine learning to enhance e-library services.

Keywords: Service-Oriented Architecture, E-library systems, Scalability, Interoperability, Digital Age

Introduction

In the digital age, libraries are evolving from conventional brick-and-mortar foundations into dynamic, electronic repositories of information. This transformation is driven by the need to provide instant, remote access to a vast array of digital resources, catering to the diverse needs of users across the globe. However, the development and management of electronic library (e-library) systems present significant challenges (Mole & Mesagan, 2017), including ensuring scalability, interoperability, and efficient resource management. Service-Oriented Architecture (SOA) has emerged as a robust framework capable of addressing these challenges. SOA's modular approach allows for the integration of diverse services and resources into a cohesive, scalable system. By leveraging SOA, e-libraries can provide seamless access to digital content, facilitate the integration of various library functions, and enhance the overall user experience (Stojanovic et al., 2004).

Meanwhile, proposed in the literature are plethora of different designs of e-library management system particularly in the areas of cataloguing information, integrating services by providing database for managing books' access and retrieval of information. Majority of these developed e-library systems targeted the university level (Agboke et al., 2020; Babatope et al., 2022) or students with limited or few attentions given to the Polytechnic's students or level (Onwueme et al., 2024). Also, as at the time of preparing this manuscript, the authors were not aware of any e-library management system design that adopted SOA principles or software development paradigm especially in sub-Sahara Africa. Moreso, traditional e-library systems are frequently constrained by rigid, monolithic architectures that are difficult to update,

integrate, or scale. This inflexibility limits the library's capacity to adapt to new technologies or incorporate additional services, resulting in a suboptimal user experience (Babatope et al., 2022; Pau et al., 2022).

Thus, presented in this research article is the design and implementation of an e-library system based on SOA principles. The proposed methodology in this study is unique and apt in this era of tremendous digital transformation. The study aims to demonstrate how SOA can be utilized to develop an efficient, flexible, and scalable e-library system that meets the evolving needs of both users and administrators. Through a detailed examination of system components, architecture, and implementation strategies, this work contributes to the ongoing discourse on the modernization of library systems in the digital era (Pau et al., 2022).

Review of Related Works

The development of electronic library (e-library) systems has become increasingly important in the digital age, as libraries transition from traditional physical spaces to virtual repositories of information is inevitable. This section reviews relevant literature by exploring the key concepts, technologies, and challenges associated with e-library systems design and development, focusing particularly on the application of Service-Oriented Architecture (SOA) to address the limitations of traditional systems.

Theoretical Review of Service-Oriented Architecture Models

Service-Oriented Architecture (SOA) is a design paradigm that structures software systems as a collection of loosely coupled, reusable services (Lasitha Chamari et al., 2023). These services can be independently developed, deployed, and managed, allowing for flexibility, scalability, and interoperability in system design. Over the years, several SOA models have been proposed and refined to address different architectural needs and challenges. This theoretical review explores key SOA models, their components, principles, and the variations that have emerged.

Evolution of Electronic Library Systems

Electronic library systems have evolved significantly over the past few decades, driven by the need to manage and provide access to digital content efficiently (Sadiku et al., 2018). Early e-library systems were primarily designed to digitize and store physical resources, making them accessible through basic search and retrieval functions. However, these systems often lacked scalability and flexibility, which limited their ability to support large, diverse collections of digital content. As user demands grew, the need for more sophisticated and smarter systems became apparent and imperative due to the integration of digital processes and informational feedback loops in the public infrastructure as this makes digital systems such as e-libraries more efficiently organized, resource-friendly, flexible, adaptable and extendible (Shah & Bano, 2020).

Modern e-libraries now encompass a wide range of digital resources, including e-books, journals, multimedia, and databases. They also support various user services, such as online borrowing, user management, and content curation. However, despite these advancements, many e-library systems still face challenges related to scalability, interoperability, and adaptability, particularly in the face of rapidly changing technological landscapes (Cooper & Zmud, 2021). So, the search for appropriate and most efficient software development approach to e-library design and implementation continues. Without any doubt, service-oriented architectural model stands tall amongst its peers in software design and development (Stojanovic et al., 2004).

Service-Oriented Architecture (SOA) in Software Development

Service-Oriented Architecture (SOA) is a software development paradigm that promotes the creation of modular, reusable services that can be independently developed,

deployed, and maintained. SOA is particularly valuable in environments where systems need to integrate diverse services and accommodate future changes without significant rework.

In the context of e-libraries, SOA offers several advantages (Sward & Boleng, 2009). By decoupling services, SOA allows for greater flexibility in system design, enabling libraries to integrate various functionalities—such as search, retrieval, and user management—into a cohesive platform. Additionally, SOA facilitates interoperability with other systems, such as Learning Management Systems (LMS), enabling seamless access to educational resources. The modular nature of SOA also supports scalability, as new services can be added or existing ones upgraded without disrupting the entire system.

Challenges in E-Library System Development

Despite the potential benefits of SOA, implementing such architecture in e-library systems presents several challenges (Omeluzor et al., 2023). One of the primary concerns is the complexity of designing and managing a service-oriented system (Stojanovic et al., 2004). Each service within the SOA must be carefully designed to ensure that it interacts correctly with other services, which requires rigorous planning and testing. Another challenge is ensuring data security and integrity, especially in environments where services are distributed across multiple servers or even geographic locations. Implementing robust security measures, such as encryption and access controls, is crucial to protect sensitive information within the e-library system (Agboke et al., 2020; Mole & Mesagan, 2017). Additionally, the need for continuous updates and maintenance of services to accommodate new technologies or user demands can strain library resources (Agboke et al., 2020).

Related Work

The literature consists of a number of related works to the current study. For instance, there are many proposed SOA models in various domains. Early works such as (Cucinotta et al., 2009), (Li et al., 2010) and (Al-Rashedi, 2014) have implemented SOA principles for industrial automation, business process execution and e-government based on cloud computing respectively. Recently, SOA systems have been proposed for small and medium enterprises with infrastructure and cost optimization (Rojas et al., 2021), data-driven smart buildings (Lasitha Chamari et al., 2023), and for Search Engine Optimization (SEO) best practices in the development of a video streaming meta platform (Terol et al., 2024). Particularly, SOA application in e-library systems has several advantages. These include reuse of services across processes, greater adaptability and efficient maintenance.

So, as regards to e-library systems, several case studies have demonstrated the successful application of SOA. For example, a study by Matthew et al. (2021) highlighted the effectiveness of SOA in enhancing the interoperability and scalability of an academic library's digital system. Similarly, another study by Babatope et al. (2022) underscores the importance of SOA in a public library system, in which the architecture can enable the seamless integration of external databases and digital resources. These are many studies of SOA in e-library's perspective. However, in the Nigerian context, there has been no e-library systems that have implemented the SOA's principles. Again, majorly proposed e-library systems in the country are not subjected to test especially using the intending users of the system. More so, by evaluating the relationship between the quality of the application and the intention to use by the users. Thus, this is the gap the proposed system wishes to fill.

Service-Oriented Architecture

Service-oriented architecture (SOA) is a software development paradigm which relies on software components called services to create business applications. Every service offers a certain business function, and they can all converse with one another in multiple languages and platforms. With SOA, developers can integrate multiple independent services to accomplish

complex tasks or reuse services across different systems (Sward & Boleng, 2009). Services communication is governed by well-established rules called communication protocols such as Simple Object Access Protocol (SOAP), RESTful, HTTP, Apache, Thrift Apache ActiveMQ, Java Message Service (JMS) etc. that are used for data transmission over a network.

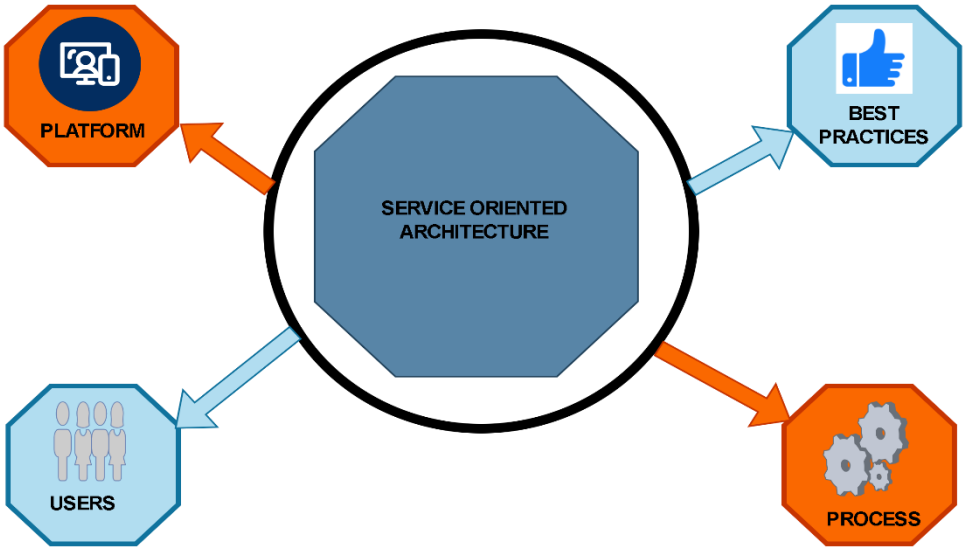


Figure 1: Service Oriented Architecture (Adapted from Medium, 2019)

As shown in Figure 1, components such as users, platform, best practices and process are well integrated in a fashion that can possibly deliver the best services in the system development.

SOA in E-Library System Development

Despite the potential benefits of SOA, implementing such architecture in e-library systems remains a daunting task with several challenges (Medium, 2019; Waris et al., 2013). The first concern is the complexity of designing and managing a service-oriented system. This is because each service within the SOA must be carefully designed to ensure that it interacts correctly with other services, which requires rigorous planning and testing. Secondly, there is a challenge of ensuring data security and integrity (Lasitha Chamari et al., 2023), especially in environments where services are distributed across multiple servers or even geographic locations. Implementing robust security measures, such as encryption and access controls, is crucial to protect sensitive information within the e-library system. Additionally, the need for continuous updates and maintenance of services to accommodate new technologies or user demands can strain library resources.

SOA E-library System (SOE-Lib)

The design process begins with stakeholder engagement through interviews of key stakeholders such as librarians, library portals, students, and faculty to gather information and detailed requirements. Followed by definitions of features which typically include user management (registration, roles), book cataloguing, search functionalities, borrowing and returning processes, fine management, and reporting tools. Then, the design of users' interface called front end. HTML, CSS, and JavaScript were front-end technologies chosen for building user interfaces because they offer robust and responsive design capabilities. While MySQL was chosen as a back-end framework for building the relational database needed as it supports the required functionality and integrates well with front-end.

The architecture presented in Figure 2 is a three-tiered SOA based modular design that facilitates ease of functionalities and integration of processes and platforms.

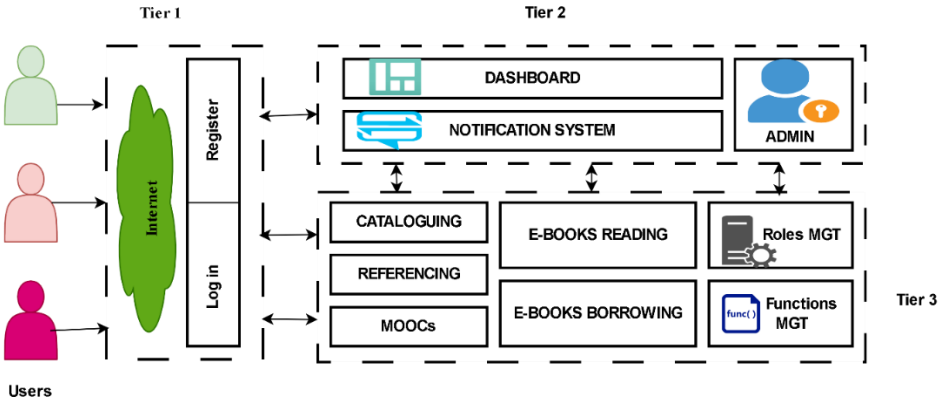


Figure 2: SOA Based E-Library Architecture

The Tier 1 layer consists of user's interface where a new user will need to register and existing user would login using various devices such as computer, tablet, laptop mobile phones or other handheld in order to access the application. Tier 2 is the portal management layer where the administrator can manage the system via the dashboard showing users' statistics and requests. A notification system is also included to alert the administrator on new messages. On the Tier 3 layer are the e-library services. For instance, cataloguing, referencing and access to other digital repositories and learning platforms via massive online open courseware (MOOCs) button. Readers can choose to read or borrow the e-books with the roles and functionalities being manage by the administrator in this layer. After the design process, the implementation was done using appropriate technologies.

Finally in the implementation, a reliable hosting service was chosen (e.g., GO54, HOSTINGER, NAMECHEAP) to set up the server environment, including configurations for security (SSL certificates, firewalls) and scalability. To deploy the application in the live environment, the database schema was migrated, initialized accordingly and we ensured that all components (front-end, back-end, database) are correctly configured and communicate effectively. The user's interface is as shown in Figure 3. It consists of several key components to deliver the implemented SOE-Library management system. In addition, it also includes other features like new arrivals page, e-gallery and news and events feeds.

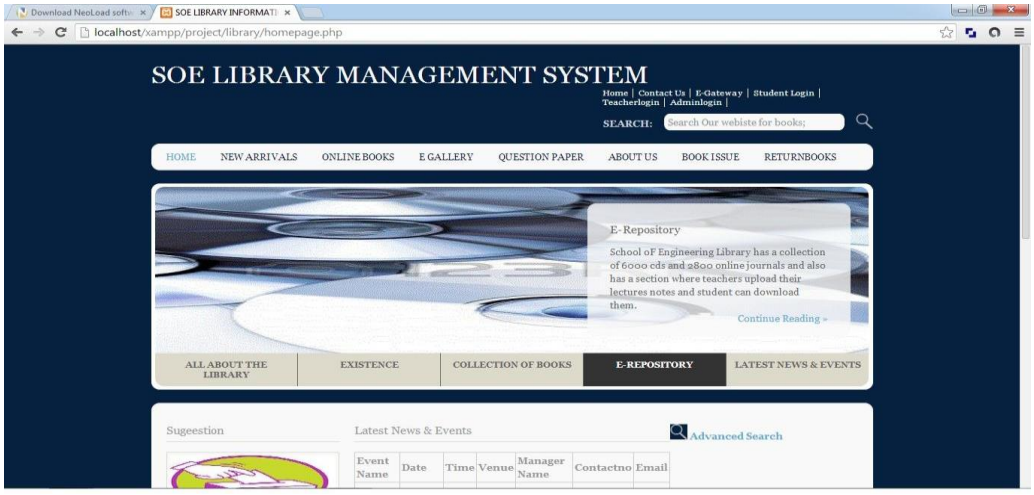


Figure 3: User's Interface of the SOE-Library System

To determine the effectiveness of the proposed system, it was subjected to test by using students to go through the system and answer few questions. Students from different departments are randomly selected to participate in the testing and a feedback quiz of nine (9) questions that takes about two (2) minutes to complete, consisting of students' demography and questions on ease of use, recommendation and users' satisfaction was served to each participating students to rate the system after use. Out of one hundred and twenty-eight (128) students, one hundred and twenty-three (123) of them completed the feedback returned for evaluation. It is of interest here that only the students who feel free and volunteered to test the system were allowed to do so and no student was coerced or forced to participate.

Results.

As earlier mentioned, the testing conducted in the preceding section involved one hundred and twenty-eight (128) students but only one hundred and twenty-three (123) of them completed the feedback constituting ninety-six percent (96%) of the responses collated. Table 1 shows the distribution of the students' participation in the study based on their departments, levels, and demography such as age, sex.

Table 1: Respondents Distribution

S/N	Department	Levels				Gender		Age Bracket			
		NDI	NDII	HNDI	HNDII	M	F	14-18	19 – 23	24 - 28	29& above
1	Accountancy	6	4	3	1	8	6	6	7	1	-
2	Business Admin	7	5	2	2	7	9	9	4	3	-
3	Comp Sc	11	8	6	5	17	13	18	8	4	-
4	Comp Engr	9	6	4	4	15	8	13	7	3	
5	Lib. Info Sci	8	4	-	-	6	6	10	2	-	-
6	Public Admin	6	5	3	1	8	7	8	5	2	-
7	Mass Comm	4	3	4	2	5	8	7	3	2	1
	Total	**51**	**35**	**22**	**15**	**66**	**57**	**71**	**36**	**15**	**1**

Survey by Authors, 2024

The survey captured the respondents' demography, department and level. This is further analyzed using percentages and bar chart for pictorial view based on the departments, age and level of the students. From Table 1, majority of the respondents are teens (58.5%) between the ages of 14years to 18years, follow by those in their late teens and post-teens (32.5%), and 8.1% of the respondents are in the age bracket 24-28 years, while just one person (0.8%) falls between age bracket of 29 years and above. The data in Table 1 and the responses of the students were encoded in the Statistical Program for Social Science (SPSS) version 26. To evaluate the system, two variables are created for the purpose of evaluation of the statements in the feedback quiz given to the students. System quality variable and the intention to use variable are used to run Pearson Correlation analysis in SPSS version 26 as shown in Table 2 and Table 3.

Table 2: The Mean and Standard Deviation of System Quality and Intention to Use Descriptive Statistics

	Mean	Std. Deviation	N
System Quality	1.3577	.36508	123
Intention to Use	1.5366	.39031	123

The mean and standard deviation of the system quality and intention to use by students are as shown in Table 2. There is a fairly spread of the data about the mean given by the value

of the standard deviation. This could be as a result of the number of students that participated in the study.

Table 3: Pearson Correlation Analysis

Correlations

		System Quality	Intention to Use
System Quality	Pearson Correlation	1	.070
	Sig. (2-tailed)		.439
	N	123	123
Intention to Use	Pearson Correlation	.070	1
	Sig. (2-tailed)	.439	
	N	123	123

Table 3 shows the result of correlation analysis of both system quality and the intention to use by students. The value for the Pearson Correlation is 0.070, this means that the relationship between the system quality variable and the intention to use variable is strong and statistically significant. Thus, the correlation is significant at 0.01 levels, and it can be concluded that the quality of the system influenced the intention to use by the students.

Conclusion and Future work

The application of Service-Oriented Architecture (SOA) in electronic library systems represents a significant advancement in the design and management of digital libraries. By addressing the challenges of scalability, interoperability, and adaptability, SOA offers a robust framework for developing next-generation e-library systems that can meet the diverse needs of users (Lasitha Chamari et al., 2023; Sadiku et al., 2018). However, the successful implementation of SOA requires careful planning, robust security measures, and ongoing maintenance to ensure the system's long-term viability (Terol et al., 2024). In this study, an e-library system based on the principles of SOA is proposed. The proposed system was tested and evaluated using students of a Polytechnic, bivariate Pearson Correlation analysis was conducted for quality of the system and intention to use by the students. The result obtained showed that the quality of the system and intention to use are strongly correlated meaning that quality of the system influenced the intention of the students to use the system.

The future of e-library systems lies in the continued adoption of flexible, scalable architectures like SOA, coupled with the integration of emerging technologies such as artificial intelligence (AI) and machine learning (ML) and cloud computing will likely shape the future of e-library systems, further enhancing their capabilities and user experience (Babatope et al., 2022). So, the authors would like to investigate how the technologies can be used to develop a more robust e-library system that can scale their services more efficiently, store and manage vast amounts of digital content, and provide users with seamless access to resources from anywhere in the world in the future.

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