International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I3P124

Volume 72 Issue 3, 268-276, March 2024

Original Article

BOSESKO: A Digital Citizen Participatory System Architectural Framework

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Received: 26 August 2023 Revised: 03 December 2024 Accepted: 28 February 2024 Published: 17 March 2024

Abstract *- The study aims to design a system framework for a multilingual, inclusive, deliberative toolkit, coined as BOSESKO (Building on Opinions and Sentiments for Sustainability and Knowledge Opportunities), that can be used on the web and mobile devices. This solicits comments and feedback from the general public to encourage digital citizen participation before a natural disaster and climate adaptation, as well as on implementing the Universal Access to Quality Tertiary Education (UAQTE) to be deployed in different communities in the Philippines towards policy formulation. It explores emerging methods in artificial intelligence, machine learning, natural language processing, and software integration for data gathering, processing, visualization, and system development. The study utilizes the descriptive method and prototyping methodology. The component-based, facade, BLOC, client-server, and cloud design architectural patterns serve as the foundation for the intended system's architectural framework. To illustrate the system's architectural approach, the use case and component diagrams are presented to highlight the methods, functions, and links between the various entities involved in the process. Multiple platforms integrated with application programming interfaces for web, mobile, and Natural Language Processing (NLP) were employed in developing the toolkit designed to work in the cloud environment. The system architectural framework was created with the end goal of providing a clear understanding of the complete system process, thus generating a positive evaluation using SAAM.*

Keywords *- Digital citizen participation, System framework, Integrated systems, Software architectural patterns, Cloud services.*

1. Introduction

The legal system in the Philippines encourages citizen participation in governance [1], reflecting the importance of civic involvement in nation-building. Eduardo M. Ao, the Chair of the Philippine Government Commission (PGC) and the Secretary of the Department of the Interior and Local Government, highlights the significance of citizen engagement in promptly addressing the needs of Filipinos [2]. While the government has made strides in promoting transparency and establishing functional citizen feedback mechanisms, global governance data on participatory governance reveals that the shrinking space for civil society remains a major challenge to advancing genuine democracy in the Philippines [1]. Consequently, governmental organizations are encouraged to assess and adapt their strategy and decision-making processes to ensure the promotion of e-participation [3]. Involving active participation of citizens can be an avenue for decision-makers to develop better public policies, particularly in addressing disaster risk management and access to high-quality education. This can be especially helpful when discussing moral and political issues for which there is no correct answer, as lay citizens might draw attention to aspects and implications that decision-makers might not otherwise be aware of [4]. Natural disasters frequently hit the Philippines due to its geographical location. The Philippines is surrounded by prominent bodies of water, including the Pacific Ocean, and is located within the Pacific Ring of Fire. Furthermore, climate change poses another risk for the Philippines, which worsens the issue by increasing the frequency of severe storms, storm surges, flooding, landslides, and tsunamis. Moreover, steps have been taken in the Philippines to address the problem of educational inequality and promote higher education enrollment.

The Universal Access to Quality Tertiary Education Act was passed in 2017, providing government coverage for student tuition and other expenses, such as school supplies, at State Universities and Colleges (SUCs). Additionally, tuition aid is available for students attending private universities [5]. To ensure the effective operation of higher education institutions, it is crucial to conduct feedback analysis on the curriculum [6]. Citizen engagement plays a significant role in formulating education policies, emphasizing the importance of considering diverse perspectives [7] and involving community members in the decision-making process [8].

Digital citizen participation is the method of using new media, interactive media, and digital information and communication technologies (ICT) to open channels of contact between the public and the government [9]. The term "e-participation" refers to how people interact with their government through digital means like the internet and smartphones, opening up new channels for engagement. [10]. Moreover, [11] referenced the study by Macintosh (2004), which introduced e-participation as using web technology to support community-driven projects while facilitating government collaboration. With this strategy, cost-effectiveness, information accessibility, transparency, and citizen participation are all improved [12]. Information and communication technology (ICT) integration inside governance systems is referred to as e-government. Its goal is to promote deeper and more extensive participation from institutions, NGOs, corporations, and citizens. In the current democratic era, e-governance has developed into a crucial feature of the participatory method [13].

To enhance and facilitate broader and more accessible public participation for improved governance, this study focuses on designing and developing an architectural framework for a multilingual, inclusive, and deliberative toolkit accessible on both web and mobile platforms. The data gathered from diverse respondents, including Local Government Units, Students, and Program Implementers, will be centralized and stored in a Cloud Server. Subsequently, these responses will undergo analysis using Natural Language Processing models to generate results and insights, contributing to more informed decision-making processes. Even with the rapid technological advances, there is still a major research gap in designing a comprehensive system framework for an inclusive, multilingual, and deliberative toolkit that can be accessed on mobile and web platforms and is specifically intended for disaster management and education policy formulation. In addition, there is no existing data-gathering tool with a Natural Language Processing (NLP) component. Thus, this study aims to fill the gap that makes use of state-of-the-art technology to improve citizen participation in governance processes. The architectural framework is the primary design incorporating natural language processing, multi-platform and system integration.

2. Related Works

This section provides background on the existing related studies concerning developing system architectural frameworks. It is emphasized in the respective studies by [14] and [15] that in order to engage citizens effectively, policymaking institutions must recognize and accept participatory governance methods and, as a result, develop listening mechanisms that take into account the citizens' knowledge, expectations, values, and envisioned plans. There could be three different levels of citizen involvement in the stages of policymaking, which include enabling, engaging, and empowering citizens [10]. Successful citizen involvement in policy formulation necessitates the use of technology features and channels developed to support online policy forums, and these features should be fine-tuned to increase citizens' ability to receive feedback, provide comments and opinions, or access decisions that have already been made [16].

E-participation is the process of engaging citizens in policy, decision-making, and service design and delivery through Information and Communications Technologies in order to make it participatory, inclusive, and deliberative [17]. In addition, the primary objective of e-participation is to involve and engage citizens in decision-making [18]. The significant increase in mobile internet users globally demonstrates the usefulness of mobile applications as a tool for involving individuals in local public affairs and decision-making processes. One identified mobile application has a function that allows citizens' opinions to be obtained through surveys on various projects or themes, making it a participatory tool [19].

Several studies were carried out with the goal of increasing public participation and open, participatory governance. This includes the study of [20], who developed a mobile app fostering citizen-government dialogue through location-based polls on planning initiatives. On the other hand, [21] introduced a multilingual web application where that serves as a space where individuals can freely express their ideas and opinions, specifically focusing on the context of Peru. An e-government portal called e-Reklamo was also developed by [22] for citizens' complaints about government services, promoting openness and good governance. Additionally, to improve online communication between citizens and public officials, Shofia et al. created a platform model framework with several features that facilitate data collecting, public participation, and sound decision-making [23].

System frameworks are necessary for the design and development of an e-participatory tool. A framework is a layered structure that outlines what kind of programs can or should be built and how they might interconnect [24]. Moreover, a system's architecture can be viewed as a type of solution principle that focuses on the system creation process. Specifically, it is defined as the assignment of functions to elements and the organization of these elements in a structure [25].

When designing software, an architectural pattern is a reusable solution to a problem that frequently arises in a specific setting [26]. The Component-Based Design (CBD) paradigm employs a cohesive set of fine-grained objects to produce coarse-grained and loosely connected components with well-defined functionality and communication interfaces. A system with functional components rather than physical objects is represented by a component-based design. Rather than using different events and algorithms for each method call, numerous functions share a single algorithm with a single generic event input [27]. Business Logic Components (BLoC), on the other hand, has a design pattern that is similar to other well-known mobile device solutions [28]. It facilitates state management and makes data accessible from a single location within a project [29].

According to [30], client machines (user devices) interact with a server over a local area network in the client-server architecture. The client handles user requests and communicates with the server, which performs data retrieval processing and provides the results to the client [31]. In addition, instead of a collection of interfaces on a subsystem, the facade pattern offers a single interface. The higher-level interface defined by the "facade" makes it easier to use the subsystem [32]. Furthermore, the difficulties involved in developing cloud applications are lessened by using cloud design patterns to build dependable, scalable, and secure cloud apps. Not making use of Cloud Design Patterns (CDP) in the development of cloud applications might result in apps that are poorly designed [33].

The previously mentioned studies and literature are interrelated with the current study and serve to expand the researcher's knowledge of existing citizen engagement systems designed to solicit feedback and suggestions, as well as the architectural patterns that will serve as the foundation for the intended system's architectural framework. The principal objective of this study is to employ technology-based approaches to provide a framework that will aid in disaster management and education policy development.

3. Methodology

For the conceptualization of the development of the BOSESKO toolkit, formerly known as *Kalahok*, the descriptive method and prototyping methodology was used as the research design, which draws inspiration from the [34] prototyping model. The prototyping approach is meant to provide an overview of the application initially, which will be evaluated by the user [35]. It entails fast and easy execution of a trial system for evaluation by the end user [36].

The prototyping methodology involves five development phases: planning, analysis, design, prototype generation, and implementation [37]. Since the study is primarily concerned with the development of the system framework, the discussion will only cover the first three stages of the methodology. In prototype generation, ideas are brought to life in this phase by creating prototypes that are in line with conceptualized ideas, which helps researchers see potential solutions visually [38]. On the other hand, all well-designed elements are implemented during the implementation phase [39]. The prototype generation and implementation phases are crucial for translating the concept into a workable system. Furthermore, the prototype will be constructed and implemented based on the designed system framework. The tasks carried out at each phase will be discussed in detail in the following subsections.

The concept integrated was the Design Thinking Process step in some phases to properly establish a comprehensive and organized framework for our target users.

Design thinking is a methodology that extends beyond professional design practice, offering a versatile approach to addressing issues and solving problems, with applications in both business and social contexts. By adapting this approach, the gathered results were evaluated through its 5 Stages: Empathize, Define, Ideate, Prototype, and Test.

3.1. Planning

During this phase, the researchers defined the objectives of the proposed system based on the identified challenges and user requirements. The BOSESKO toolkit will be composed of two domains intended for: (1) consulting communities on various aspects of their community DRRM plan and (2) gathering feedback from the beneficiaries of the UAQTE.

The planning phase for the Disaster Risk Reduction-Climate Change Adaptation (DRR-CCA) domain centered on holding partnership meetings and field visits to the concerned sectors, specifically in APSEMO, Legazpi CDRRMO, and Barangay-50 Padang. Further, an exploratory meeting with the Legazpi City Disaster Risk Reduction Management Office (CDRRMO) and a visit to Barangay Padang were held to have an initial exchange of ideas with regard to the development of the toolkit.

Furthermore, the planning phase for the second domain focused on developing the UAQTE Survey Questionnaire with Commission on Higher Education (CHED) Region V personnel and stakeholders. The BOSESKO toolkit for the UAQTE aims to include survey questions suitable for gathering feedback from program beneficiaries, specifically the students. These questions should effectively measure the impact of tertiary education programs on the beneficiaries and identify challenges, issues, and concerns from the perspective of program implementers and other stakeholders. Formulating and developing the survey instrument are crucial steps in ensuring reliable responses and generating valuable insights and data. In order to effectively draft and formulate the survey instrument, a Focus Group Discussion (FGD) was conducted with participants divided into two groups, one consisting of beneficiaries and the other of program implementers. The FGD was valuable for obtaining inputs from stakeholders and understanding their viewpoints.

3.2. Analysis

Careful analysis is crucial in the development of the system. This phase translates the pertinent data gathered into system requirements.

3.2.1. Empathize

This study's main objective is to build an architectural framework for an e-participatory toolkit. From this, empathizing with its target stakeholders was necessary, this includes the conduct of meetings and interviews with the target stakeholders. For DRRM, Local Government Units (LGUs), Civil Society Organizations, and community members. While for UAQTE, CHED UniFAST Personnel and Higher Educational Institutions (HEIs).

3.2.2. Define

During this phase, primary concerns were recognized based on the collected data from the first step. The study's objectives were to formulate an architectural framework to improve the involvement of digital citizens and foster transparency within the BOSESKO platform.

3.3. Design

In this phase, the researchers incorporated the user specifications and requirements into technological designs to establish the various study features. The main features of the BOSESKO toolkit include survey management, domain management, and generation of reports.

3.3.1. Ideate

In the ideation phase, brainstorming sessions were conducted to generate innovative concepts and ideas for the architectural framework of the e-participatory toolkit.

3.3.2. Prototype

The relevant data gathered and analyzed was utilized to illustrate a prototype of the system's architectural framework, which will serve as its tangible representation subject for further testing. This prototype included key features and design elements discussed during the ideation sessions. A Use Case Diagram was used to support the technical design and to define the high-level functions and scope of BOSESKO while identifying interactions between the toolkit and its users. To make it easier to facilitate the different functionalities based on the displayed diagram, this phase describes the functionalities leading to the design of the system architectural framework to connect all the system's various components and support the development of the toolkit in a flexible setting.

In addition, one of the key elements affecting how well an application performs is the database design. As a result, the database's design was carefully considered to effectively arrange the data based on anticipated usage patterns, system workflows, and future roadmaps.

The system's user interface design was also considered since it focuses on predicting what users may need to accomplish and ensuring that the interface features simple components to find, comprehend, and apply to assist those tasks.

3.4. Evaluation

3.4.1. Testing

An evaluation test of the conceptualized architectural framework was performed from the conducted analysis to validate the system architecture's viability and effectiveness. Mentioned stakeholders were once again actively engaged with the updated architectural framework. This iterative testing approach ensures that the proposed modifications successfully enhance usability, address any usability issues, and align with stakeholders' expectations. Further, this study was based on the study of [40], wherein they evaluated the architecture using the Software Architecture Analysis Method (SAAM). The primary objectives of SAAM focus on assessing software architectures to their intended quality attributes. SAAM lies in employing scenarios and a framework for creating and examining these scenarios [41].

4. Results and Discussion

This section shows the result of the conceptualization and analysis conducted with stakeholders throughout the methodology process. Challenges in empathizing with target stakeholders, particularly in DRRM and UAQTE contexts, are found to be the primary issues to be addressed. The use case diagram serves as a visual representation of the relationships between entities and use cases in the proposed system.

Figure 1 shows four distinct entities or actors with access to the system: respondents, the admin, the agency, and the focal person. For the respondents, their access to the system involves choosing a domain and answering surveys. After completing the survey, users can review their answers before submitting. Additionally, respondents can choose to view reports that present statistical data based on all the responses recorded by the system.

On the other hand, the administrator, the agency, and the focal person have more extensive access privileges within the system. Users may log in using their credentials, and, in case of a forgotten password, users have the option to reset it. In addition to logging in, the agency and the focal person can utilize three additional functionalities: domain management, survey management, and generation of reports. Meanwhile, the administrator holds complete control and has the full range of access functionalities provided by the system. This includes accessing Natural Language Processing (NLP) outputs, managing privileges for different users, and overseeing system account management.

BOSESKO comprises different subsystems integrated into one framework, as shown in Figure 2. The framework provides three user interfaces: a survey toolkit for web and mobile applications and a data visualizer. The survey toolkit. The survey toolkit is used for data gathering, while the data visualizer module is for report generation.

Specifically, the survey toolkit of the web application is derived from the access manager, domain manager, survey manager, and question manager data. The data warehouse component provides a port for storing the web application's configuration. Additionally, this component consolidates and visualizes the data from the web and mobile applications.

The mobile application's survey toolkit mimics the web application toolkit through the data warehouse component. It also has a response uploader component that transfers data from the mobile device to the data warehouse component. On the other hand, the data miner component's data analyzer relies on the Natural Language Processing (NLP) model. This component retrieves its data from the data warehouse.

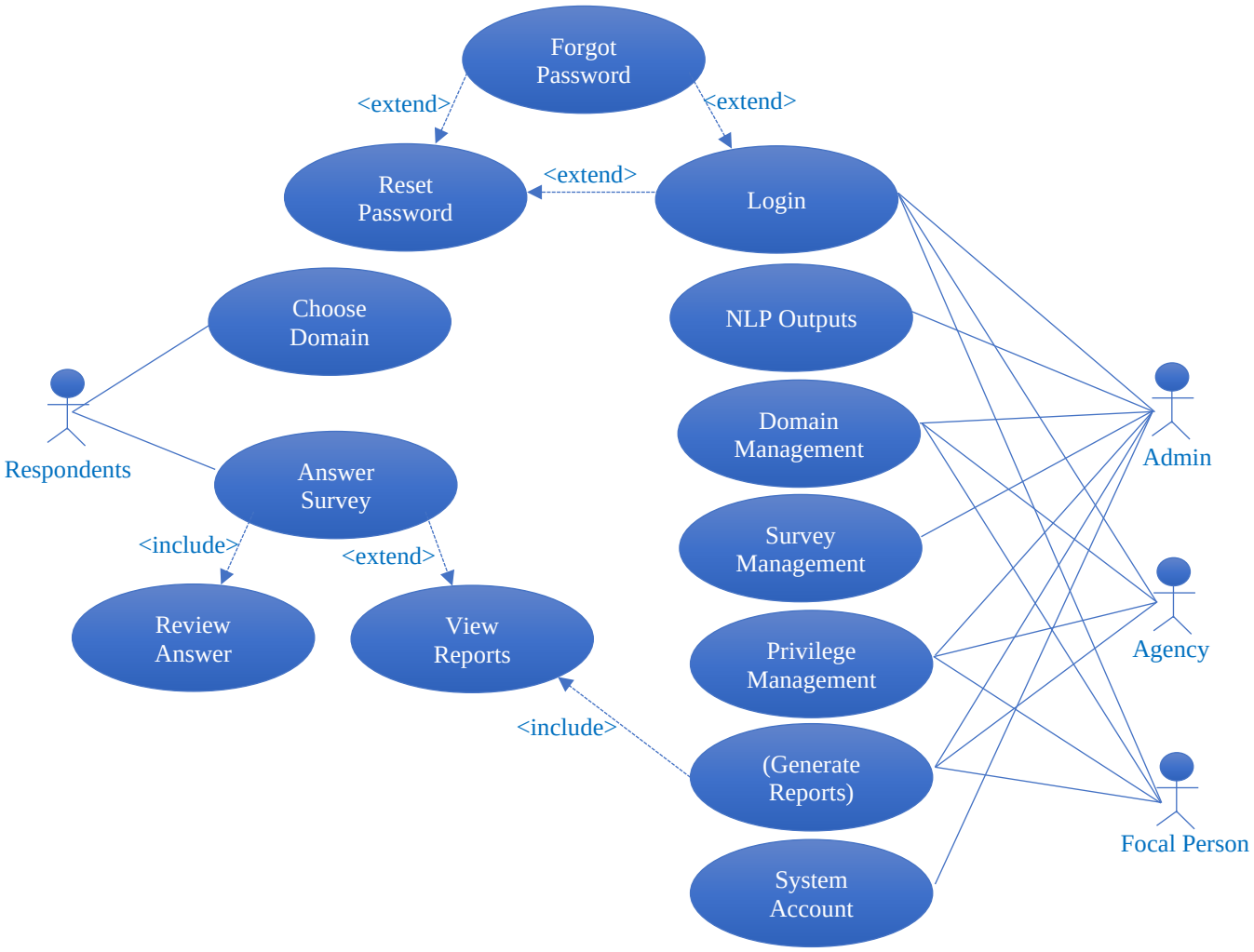

Fig. 1 Use case diagram

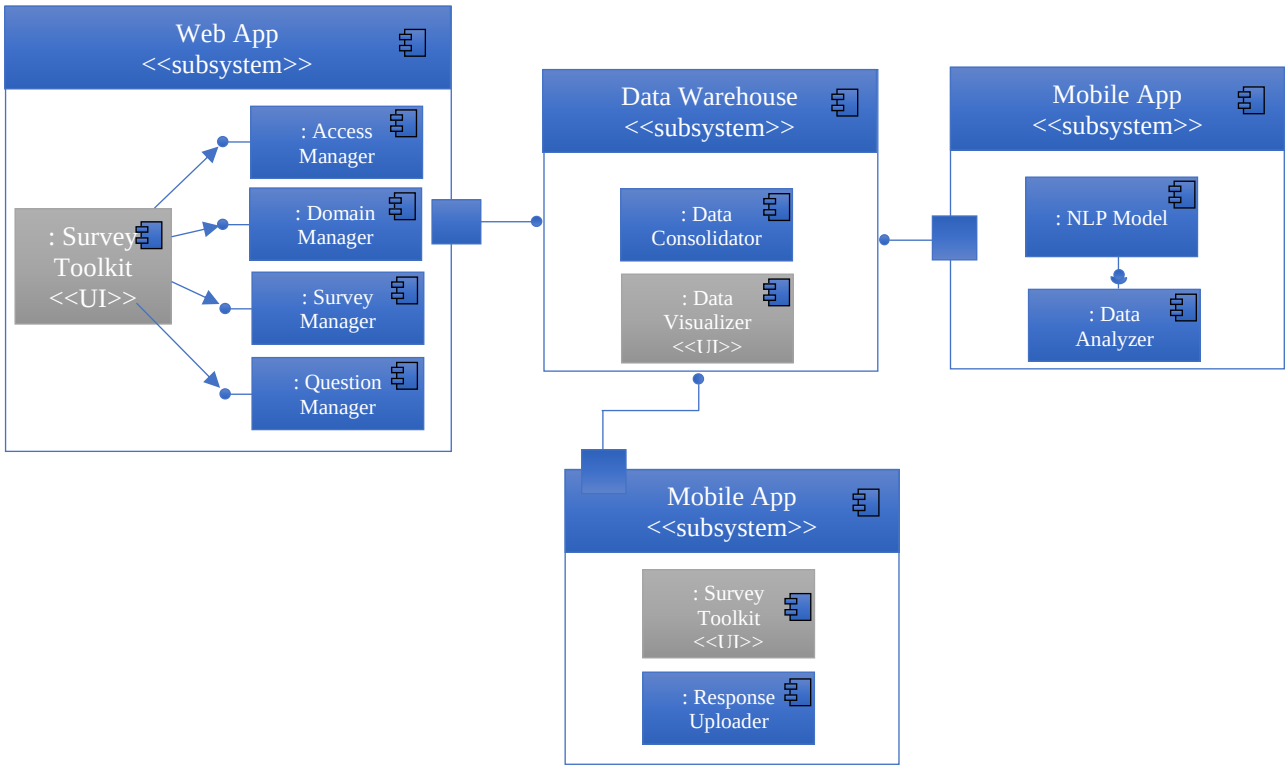

Fig. 2 Component diagram

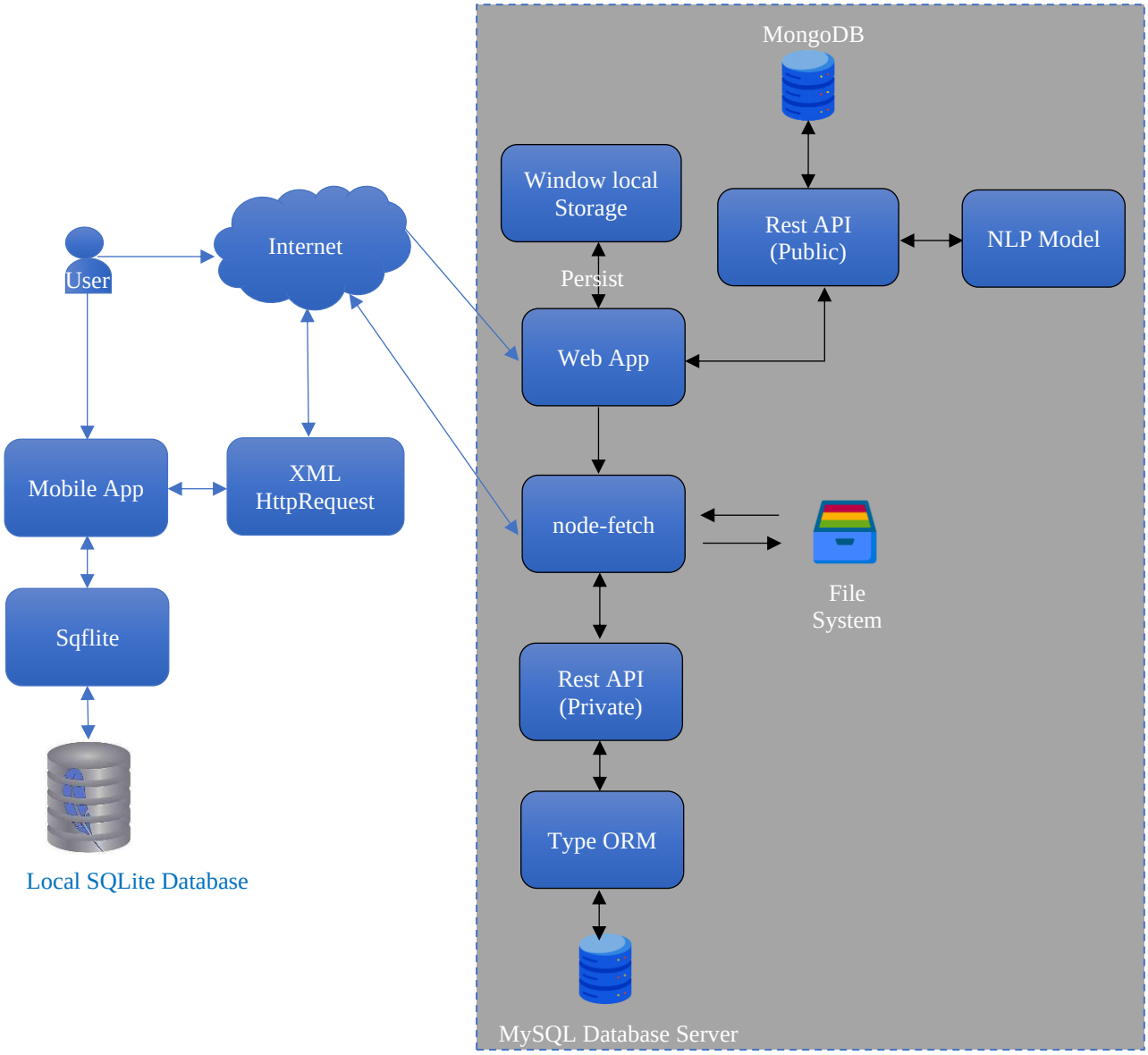

Fig. 3 Designed for the web and mobile apps

The system aims to gather input about disaster risk reduction and feedback from UAQTE beneficiaries to include the community in governance actively. The system architectural framework presented in Figure 3 is designed for the web and mobile apps, both intended to offer users a seamless experience. Multiple design patterns were employed to build the integrated system architectural framework. The web app is hosted on a cloud server and accessible to users via the internet, and users can also use the mobile app installed on their Android or iOS devices. This method uses the client-server and cloud design patterns. The browser's local Storage function enables effective data storage and retrieval within the web app. Through this, the app can save data, such as survey responses, before the user submits them, which utilizes a facade design pattern. The web app also links with a Private/Public REST API. The node-fetch function, which provides a seamless connection with the API, makes this integration possible. The integration shows a component-based design pattern.

The system architecture relies heavily on the Public REST API. It utilizes a learned NLP model to generate data analysis while running queries on unstructured data stored in a cloud MongoDB database. On the other hand, retrieving and adding audio and image files to the file system are handled by the Private REST API.

This process applies the decorator design pattern. Additionally, the Private REST API connects to a cloud MySQL database server and uses the TypeORM library to map data to it.

The SQFLITE library was used to develop the mobile app, which connects to its local SQLite database, implementing the Business Logic Components (BLoC). This database temporarily stores user input data, such as survey responses, within the app. The mobile app uses the internet-based XTML HttpRequest to integrate data into and out of the Private REST API by applying the widget design pattern. Table 1 shows the evaluation results using SAAM.

Table 1. SAAM evaluation results

Scenario			Status	BOSESKO Framework Features
No.	**Quality Attribute**	**Description**		
1	Security	System should be secured for users and systems	Implemented	• Presence of SSL • Encrypted passwords • Secured cookies • Presence of API key guard strategy to all available API • Presence of JWT based authentication for private APIs
2	Security	System should be able to prevent attacks that may compromised the accessibility and stability of the system	Implemented	• Presence of Rate Limiter for DDoS attacks • Google Recaptcha • Strict-Transport-Security Headers
3	Interoperability	System should be portable	Implemented	• APIs are available for integration • System works on different platforms
4	Portability	System data should be moved to other systems	Implemented	• Data migration features using Microservices
5	Performance	System should effectively handle an increased user load	Implemented	• Dynamic cloud environment
6	Reliability	System should ensure the accuracy and integrity of data	Implemented	• Data input validation • Error management
7	Reliability	System should be transparent when it comes to failures	Implemented	• Auditable transactions using logs
8	Usability	System should be able to accommodate different data formats	Implemented	• NLP functionalities for unstructured data • Speech-to-text conversion • Audio recording • Structured data input processing
9	Scalability	System should be scalable	Implemented	• Complete API Documentation
10	Modularity	System components should be modular	Implemented	• Independent Frontend and Backend modules

Regarding the status, all scenarios were addressed and implemented as system features of BOSESKO. This depicts all the characteristics and overall evaluation of the framework.

The system architecture framework prioritizes stability, speed, optimization, and performance while utilizing effective technologies in the industry. The framework guarantees an effective and reliable platform for gathering comments and opinions on disaster risk reduction and feedback from UAQTE recipients through carefully selecting these technologies.

Moreover, the need for robust privacy and security measures to ensure that the rights and interests of citizens within the digital participatory system are protected is considered in the design of the system's architectural framework. The potential risks and challenges associated with collecting, storing, processing, and utilizing citizen-generated data are likewise recognized, thereby providing measures to ensure data protection, informed consent, and responsible data governance.

4. Conclusion

This study developed a framework integrating multiple applications on web and mobile platforms. The integration through the Application Programming Interface (API) allows for sharing of data resources, even using different technologies. BOSESKO framework has a report-generation function for structured data and an NLP model that can perform data analysis and visualization on unstructured data. It is designed to run in the cloud environment. The framework is built utilizing a variety of design patterns for scalability, portability, interoperability, security, modularity, usability, and performance. In conclusion, a well-designed architectural framework is essential to such systems' success and long-term viability. The system architectural framework is designed for flexible, user-centric, and scalable web apps and mobile apps that may support a range of participatory models and processes. A digital citizen participatory system architectural framework contributes significantly to the evolving digital citizenship and participatory governance field. It provides a solid foundation for future research, collaboration, and implementation of inclusive and citizen-centered

approaches in the digital sphere. By adopting this framework, this study aims to foster a society where every individual has a voice and actively participates in decision-making, ultimately leading to better policy outcomes.

Funding Statement

Philippine Commission on Higher Education (CHED) Leading the Advancement of Knowledge in Agriculture and Science (LAKAS) Project No. 2021-007, eParticipation 2.1: Harnessing Natural Language Processing (NLP) for Community Participation.

Acknowledgments

The researchers would like to thank the Philippine Commission on Higher Education (CHED) Leading the Advancement of Knowledge in Agriculture and Science (LAKAS) Project No. 2021-007, eParticipation 2.1: Harnessing Natural Language Processing (NLP) for Community Participation, for providing the necessary funds to make this research possible. The researchers are truly grateful for their contribution to the research.

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