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UML-Based Design and Kano Evaluation of an Augmented Reality Library Application

Gerson Feoh[1*] , Ni Putu Ria Anggreni[2]

[1,2]Computer Science Program, Dhyana Pura University
Jl. Raya Padang Luwih, Tegaljaya, North Kuta, Badung Regency – Bali, Indonesia

e-mail: [1]gerson.feoh@undhirabali.ac.id, [2]riaanggreni34@gmail.com

(*) Corresponding Author

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Abstracts – The application of Augmented Reality (AR) technology in library services has the potential to enhance the user experience through more interactive and engaging information presentations. This study aims to create an augmented reality (AR) book search system that uses marker-based tracking to help students find references at the Dhyana Pura University Library, while also measuring how satisfied users are using the Kano Model. The system was created using the waterfall approach for developing software and used Unified Modeling Language (UML) to outline how activities flow and how different parts of the system connect. The satisfaction test involved 54 respondents, with attribute analysis using the Kano Model and Customer Satisfaction Coefficient (CSC). The results of the study show that most of the application features fall into the *Attractive* category, which indicates that these features provide added value and a positive experience for users. The combination of UML-based system design and evaluation with the Kano Model was successful in creating a library application that is functional, easy to use, and focused on user satisfaction.

Keywords: Augmented Reality, Kano Model, Library, Marker-Based Tracking, UML.

INTRODUCTION

The development of information technology over the past decade has brought significant changes in the way humans access and manage information. These changes have prompted universities to transform their academic services, including the management and utilization of libraries. At Dhyana Pura University, preliminary internal data collected up to 2025 indicate that only 18% of registered students reported using the existing library catalog application at least once per semester, suggesting a relatively low level of engagement with current library services. Interviews with library administrators revealed that students often have difficulty finding the books they need, have limited time, and that interactive and engaging library services are not yet available. In this context, Augmented Reality (AR) technology has the potential to be a solution by presenting digital information directly in the physical environment through mobile devices, as discussed in a comprehensive study on AR technology and applications by Billinghurst et al., (2021). Various studies show that the application of AR can increase the appeal and interactivity of digital media in various fields, such as education and learning media, through the presentation of three-dimensional objects and rich visualizations on mobile devices. This increase in interactivity is demonstrated, among others, in the research by Angelina and Putra (2021) Putri et al. (2023), who developed an Android-based AR application as a medium for information and learning. Sari and Yuliani (2022) studied AR-based library navigation systems and found that adding AR to information systems in libraries can also make the user experience better and speed up the process of finding references. However, most of the AR application developments still focus on technical implementation and improving the overall user experience, without a structured evaluation of the features that most influence user satisfaction.

A systematic system design approach is necessary to ensure targeted and sustainable AR application development. *Unified Modeling Language* (UML) is commonly used as a tool to help match what users need with how the system works by providing clear visual diagrams, as discussed by Rafiq et al. (2022) in their study on improving UML-based software design. The application of UML in developing library information systems has also been reported to reduce design errors and facilitate the implementation process, as demonstrated by Mulyono and Prihandoko (2023) in the development of a Waterfall SDLC-based library management system. On the other hand, user satisfaction evaluation requires an approach that can identify the role of each feature in user perception.

The Kano model provides an evaluation framework for grouping system attributes based on their impact on user satisfaction, as applied by Ramadani et al. (2024) in evaluating the quality of digital application services.

However, previous studies generally still separate the aspects of system design and user satisfaction evaluation. The development of AR applications in the fields of education and libraries tends to stop at the design and usability testing stages, without systematically linking them to quantitative models of user satisfaction. In addition, the use of marker-based AR specifically to support book searches in college library environments is still relatively limited, even though the marker-based tracking approach has been widely used in AR learning applications, as shown in the research by Adi and Nugroho (2020). This gap indicates the need for research that proves that AR is attractive and identifies the design elements that contribute most to improving the user experience.

Based on this background, this study aims to design an augmented reality-based book search application at the Dhyana Pura University Library using the UML approach and to evaluate the level of user satisfaction with the application's features using the Kano Model. The system was developed using the Waterfall System Development Life Cycle (SDLC) model because it is a clear and organized way to create systems with specific requirements, as noted by (Basten & Mellis, 2021) in their review of the Waterfall model in software engineering. This integrated approach is expected to produce a system that not only functions technically but also aligns with user needs and expectations for modern library services.

RESEARCH METHOD

This study uses a **quantitative** approach with *a System Development Life Cycle (SDLC) Waterfall-based* system development method. The *Waterfall* model was chosen because it provides a systematic, structured, and easy-to-apply workflow in application development projects with a clear scope (Basten & Mellis, 2021). This model consists of five main stages: (1) *requirement* definition, (2) *system* and *software* design, (3) implementation and *unit* testing, (4) *integration and system testing*, and (5) *operation* and maintenance. Each stage is carried out sequentially, where the results of one stage form the basis for the next stage, so that changes can be controlled effectively (Rafiq et al., 2022).

1. System Requirements Analysis

At the system requirements analysis stage, user and system requirements were explored through direct observation, interviews with library managers, and questionnaires distributed to students. These three techniques were chosen because they can produce more comprehensive and validated system requirements while reducing the risk of missing requirements in the next design stage. This approach follows the Waterfall SDLC model principle, which highlights the need for clear and documented requirements at each development stage to help manage changes effectively.The results from analyzing the requirements are then used to create a UML model, which past research has shown is good at keeping track of how user needs connect to system features and helps prevent design mistakes during implementation. So, choosing to use observation, interviews, and questionnaires during the requirements analysis stage is not just a routine step, but a smart strategy to make sure that the UML design and implementation of the AR application really meet the actual needs of library users.

2. System Design Using UML

The system design was carried out using Unified Modeling Language (UML) as a tool to visualize the relationships between system components and activity flows in the application(Suryono et al., 2021). A similar approach was adopted by Dijaya and Nasrulloh (2025) in the development of a web-based guidance and counselling information system, where the implementation of a structured model ensured the uniformity of system components. UML was used to describe user interactions, activity sequences, class, and communication between system modules. Four types of diagrams were used, including use case diagrams, activity diagrams, sequence diagrams, and class diagrams. The UML design stages were carried out to ensure that the designed system structure met user needs and could serve as a basis for the next implementation stage. According to Mulyono and Prihandoko (2023), the application of UML in library information system development helps reduce design errors and improve consistency between system components. The visualization results of the three UML diagrams are described in detail in the UML Description and System Component Integration section as part of the design implementation results.

3. Implementation of AR Applications with Marker-Based Tracking

The system implementation was carried out using the marker-based tracking method, where each marker recognized by the camera triggers the display of three-dimensional objects on the device screen(Adi & Nugroho, 2020). Each book cover is used as a marker and is linked to 3D content in the form of book information, shelf location, and synopsis. When the camera detects a marker, the application displays a 3D object that can be rotated and enlarged by the user. The marker-based tracking method was chosen because of its high accuracy and fast response time compared to the markerless tracking method (Billinghurst et al., 2021). The implementation was carried out using the Vuforia Engine integrated with Unity 3D, where developers can set the position of objects, manage the marker database, and conduct direct testing of visualization stability.

4. Evaluation Using the Kano Model

User satisfaction evaluation was conducted using the Kano Model, which serves to identify system attributes based on their influence on user satisfaction levels. This model divides attributes into five categories, namely Attractive (A), One-Dimensional (O), Must-be (M), Indifferent (I), and Reverse (R) (Wu & Chen, 2022). The research instrument was compiled based on 35 application feature attributes grouped into eight dimensions: system (S), reliability (R), ease of use (K), content (C), user interface (U), multimedia display (MD), support services (LP), and performance (PP). Each attribute was assessed using two types of questions, namely functional and dysfunctional, to determine users' perceptions of the presence or absence of a feature. This approach refers to the evaluation model developed by Li and Xiao (2020), in which each combination of functional and dysfunctional answers is converted into a Kano category based on a standard evaluation table. A similar model was employed by Ramadani et al., (2024) in their analysis of digital application service quality, where the results demonstrated that attributes with delighters values exerted the greatest influence on positive user perceptions. To determine the contribution of each attribute to user satisfaction, calculations were performed using the Customer Satisfaction Coefficient (CSC) as used by Pinem et al., (2024) and Hidayat and Sulastri (2023), with the following formula:

$$Better = \frac{A+O}{(A+O+M+I)} \quad (1)$$

$$Worse = \frac{A+M}{(A+O+M+I)} \quad (2)$$

Explanation of symbols:

- **A** = number of respondents who rated the attribute as *Attractive*
- **O** = number of respondents who rated the attribute as *One-Dimensional*
- **M** = number of respondents who rated the attribute as *Must-be*
- **I** = number of respondents who rated the attribute as *Indifferent*

The *Better* value indicates the extent of satisfaction improvement if the attribute is present, while the *Worse* value indicates the extent of satisfaction decline if the attribute is absent. The higher the *Better* value and the lower the *Worse* value, the more important the attribute is in improving user satisfaction (Perangin-angin & Sihotang, 2023). The respondents consisted of 54 active students from the Information Technology Study Program at the university. A purposive sampling technique was employed, as the respondents were selected based on specific criteria, namely, students who were familiar with or had the opportunity to use the developed augmented reality library application. The questionnaire data was processed by calculating the *Better* and *Worse* values for each attribute, then grouped based on the dominant category (*A*, *O*, *M*, *I*, or *R*). Based on the calculation results, 28 attributes were classified as *Attractive*, 6 as *Indifferent*, and 1 as *One-Dimensional*. Based on the *Better* and *Worse* calculations for each attribute, the category of each feature was determined using dominant classification (*Attractive*, *One-Dimensional*, *Indifferent*, *Must-be*, or *Reverse*). The complete analysis results are explained in the User Satisfaction Analysis Results Using the Kano Model section.

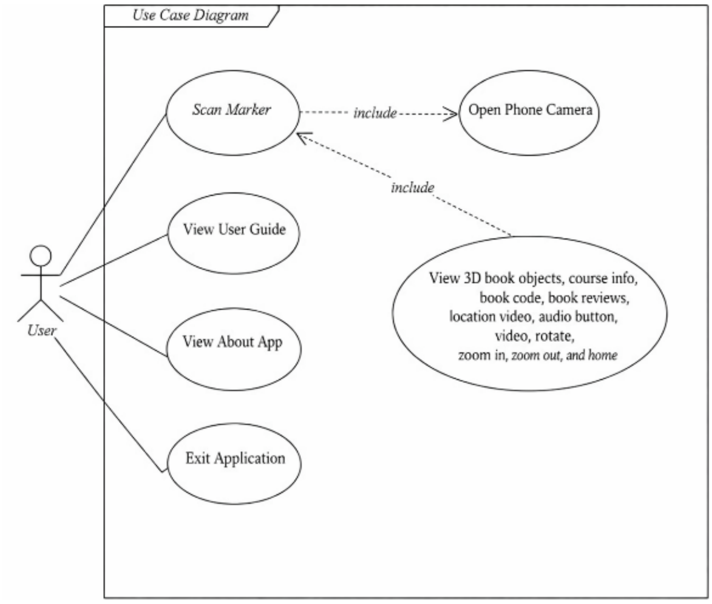
RESULTS AND DISCUSSION

This section discusses the research results, which include system design using *Unified Modeling Language* (UML), the results of the implementation of the library *Augmented Reality* (AR) application, user satisfaction analysis using *the Kano Model*, and interpretation of the results and implications for development. Each stage is explained sequentially according to the system development process. The design of the library *Augmented Reality* application system was carried out using four main diagrams in *Unified Modeling Language* (UML): *Use Case Diagram*, *Activity Diagram*, *Sequence Diagram*, and *Class Diagram*. These four diagrams serve to visualize the logical structure of the system, the workflow of the application, and the relationships between components before implementation.

1. Use Case Diagram

This diagram illustrates the interaction between users (actors) and the system. The main actors are students as application users, with four main activities:

- **Scanning book markers** to display book information in the form of 3D objects.
- **Viewing book information**, including the title, author, and location on the bookshelf.
- **Accessing the user guide**, in the form of an interactive video.
- **Exiting the application** to end the usage session.

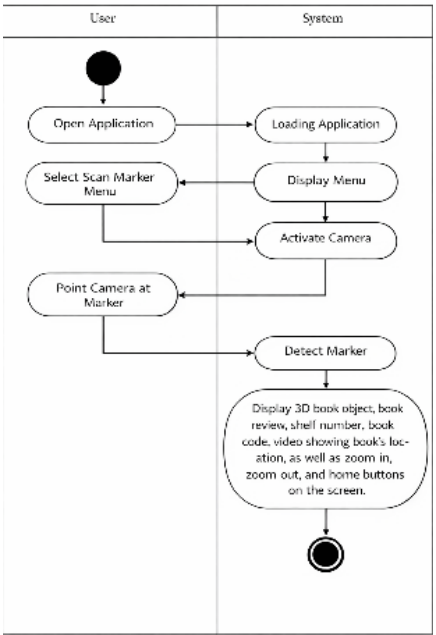


Source: Research Result (2025)
Figure 1. Use Case Diagram of the Library AR Application

Figure 1 shows the direct relationship between the user and the system through the main interface. The activity "displaying book information" can only be performed after a successful "marker scan." This diagram serves as a reference in defining the functional requirements of the system.

2. Activity Diagram

The activity diagram explains the application process flow from start to finish. The process begins when the user opens the application, selects the *Scan Marker* menu, and then points the camera at the book marker. If the marker is recognized, the system displays a 3D object with book information. If not, the system displays an error message and asks the user to repeat the process.

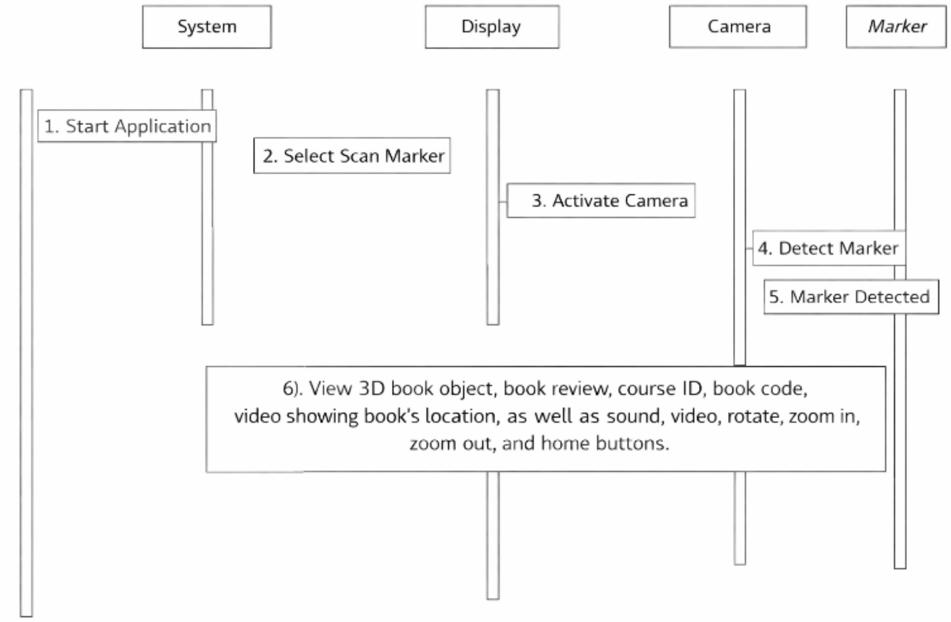


Source: Research Result (2025)
Figure 2. Activity Diagram of the Library AR Application Scan Marker

Figure 2 shows a *decision node* that determines the success of marker detection. This diagram describes the system control flow in detail, making it easier for developers to understand the operational logic of the application. The scan marker activity diagram begins with the user opening the application and the system displaying the main menu, then the user selects the scan marker menu to scan the book cover marker. then the system displays the camera screen and the user points the camera at the marker. If the system detects the marker, it will display a 3D object of the book, course, book code, book content review, video showing the book's location, as well as audio, video, rotation, zoom in, zoom out, and home buttons on the screen.

3. Sequence Diagram

The sequence diagram shows the order of communication between system components. When the user scans the marker, the camera captures the image and sends it to the Vuforia Engine for identification. The system matches the detection results with the marker data stored in the database. If valid, the 3D object will be displayed on the user's screen.

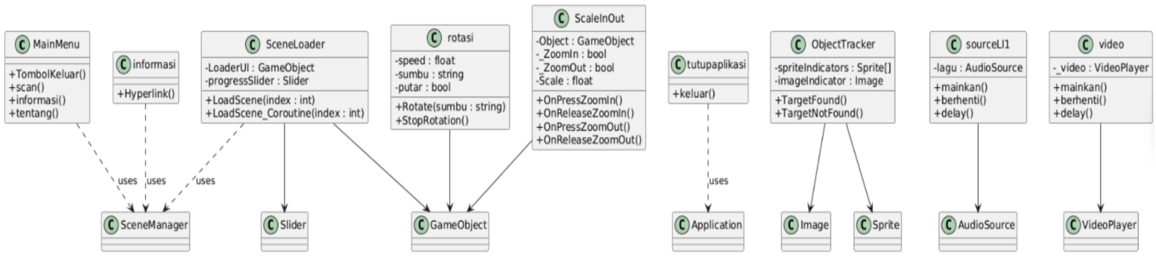


Source: Research Result (2025)
Figure 3. Sequence Diagram of System Component Interaction for AR Library Application Marker Scanning

Figure 3 shows the synchronous interaction between the user, camera, Vuforia Engine, and display module. This diagram helps ensure that the communication process between components is efficient and follows a logical sequence. This marker scan sequence diagram begins with the user opening the application and the system displaying the main menu, then the user selects the marker scan menu to scan the book cover marker. then the system displays the camera screen and the user points the camera at the marker. If the system detects the marker, it will display a 3D object of the book, course, book code, book content review, video showing the book's location, as well as audio, video, rotation, zoom in, zoom out, and home buttons on the screen.

4. Class Diagram

The final stage in system design using UML is the preparation of a Class Diagram that represents the internal structure of the software. This diagram is used to illustrate how each class, attribute, and method interacts in forming the overall logic of the application. Through the Class Diagram, the relationships between system elements such as interface management, data processing, and multimedia functions can be clearly mapped. This diagram also plays an important role as a bridge between the design and implementation stages, as it defines the blueprint for the program code to be developed in the Unity 3D environment. With the Class Diagram, developers can ensure that each system component has specific responsibilities and is connected in a modular manner.



Source: Research Result (2025)
Figure 4. Class Diagram of the AR Library Application Class Structure

Figure 4 shows the structure of the library AR application class, which consists of several main classes and methods that interact with each other to run the system's functionality. The MainMenu class functions as the main navigation controller of the application with the scan(), information(), and about() methods. The information class provides the Hyperlink() function to access digital guides, while SceneManager and SceneLoader manage page transitions (scene management). The rotation and ScaleInOut classes manage user interaction with 3D objects, while ObjectTracker handles the marker detection process using the Vuforia Engine. The sourceL1 and video classes manage audio and video playback within the application. The relationship between classes is uses or association, indicating that the classes use each other's functions without direct dependency. This structure is modular, facilitating maintenance and further development. This approach supports the research of Mulyono and Prihandoko (2023), which confirms that the use of UML in the design stage can improve the efficiency and consistency of multimedia-based information system development.

5. System Implementation

The library Augmented Reality (AR) application is implemented using Unity 3D and Vuforia SDK with a marker-based tracking approach. Each book in the library has a marker in the form of a cover image that serves as a visual marker to display digital information. When the smartphone camera detects the marker, the system displays a three-dimensional object containing book information such as the title, author, synopsis, and book shelf location. The application interface consists of four main menus, namely Home, Scan Marker, Guide, and About the Application. The Home menu displays the main features, while Scan Marker activates the camera for marker scanning. The Guide menu provides interactive videos to help users understand the application's functions, and About the Application displays developer information. Test results show that the application is capable of detecting markers with high accuracy at an optimal distance of 15–40 cm under normal lighting conditions. The average response time from scanning to the appearance of the 3D object is 1.8 seconds. Objects can be enlarged and rotated with screen gestures, providing an immersive interactive experience.

Source: Research Result (2025)
Figure 5. Marker Scanning Feature Interface Display

Figure 5 shows the interface display when the user points the camera at the book marker. The text "Point at the book cover" appears as a visual guide. Once the marker is recognized, the system automatically displays the 3D model of the book and related information.

Source: Research Result (2025)

Figure 6. Application Usage Guide Feature Display

Figure 6 shows the application guide page that explains the steps for use. This guide consists of nine sections covering button functions, object rotation, and media playback. The guide is designed with an informative visual display so that it is easy for new users to understand. The implementation of this interface results in an intuitive, efficient, and easy-to-use application. The simple visual design with a clear menu structure allows users to understand the main functions without requiring additional training. This supports the research by Adi and Nugroho (2020), which shows that marker-based tracking provides detection stability and fast response in the development of Augmented Reality-based systems.

6. User Satisfaction Analysis Results Using the Kano Model

User satisfaction was evaluated based on 35 application feature attributes using the Kano Model. Data was collected from 54 active students enrolled in the Computer Science Program at Dhyana Pura University. The analysis was conducted in three stages:

- Categorization of attributes based on respondents' answers,
- Determination of each attribute category using Blauth's Formula, and
- Calculation of the satisfaction index (SI) and dissatisfaction index (DI) using the Better–Worse formula.

Determination of each attribute category using Blauth's Formula, which takes into account the proportion of six basic categories (Must-be, One-dimensional, Attractive, Indifferent, Reverse, and Questionable). The results are shown in Table 1 below.

Table 1. Results of Determining the Category of Each Attribute Using Blauth's Formula

No	Code	Category	No	Code	Category	No	Code	Category
1	Bachelor's Degree	Attractive	13	K2	Attractive	25	A2	Attractive
2	S2	Attractive	14	K3	Attractive	26	A3	Attractive
3	S3	Attractive	15	U1	Indifferent	27	LP1	Attractive
4	S4	Indifferent	16	U2	Attractive	28	LP2	Attractive
5	HP1	One-Dimensional	17	U3	Attractive	29	LP3	Indifferent
6	HP2	Attractive	18	R1	Attractive	30	PP1	Attractive
7	HP3	Attractive	19	R2	Attractive	31	PP2	Attractive
8	HP4	Attractive	20	R3	Attractive	32	PP3	Attractive
9	C1	Attractive	21	MD1	Attractive	33	H1	Indifferent
10	C2	Attractive	22	MD2	Attractive	34	H2	Indifferent
11	C3	Attractive	23	MD3	Attractive	35	H3	Indifferent
12	K1	Attractive	24	A1	Attractive			

Source: Research Result (2025)

Based on the table, out of a total of 35 attributes:

- 28 attributes fall into the Attractive category,
- 6 attributes fall into the Indifferent category, and
- 1 attribute falls under the One-Dimensional category.

The majority of *Attractive* attributes indicate that improving feature performance increases user satisfaction, while *Indifferent* attributes have no significant effect on satisfaction, and *One-Dimensional* attributes show a linear relationship between performance and satisfaction. The next step is to calculate the Satisfaction Index (SI) and Dissatisfaction Index (DI) using the Better–Worse Formula. The SI value describes the extent to which feature performance improvements increase user satisfaction, while the DI shows the effect of performance decline on user dissatisfaction, as shown in Table 2.

Table 2. Results Of The Satisfaction And Dissatisfaction Calculation Using The Better–Worse Method.

Code	SI	DI	Category	Description
S1	0.56	-0.22	Attractive	Application startup speed
S2	0.54	-0.20	Attractive	Application content opening speed
S3	0.57	-0.20	Attractive	Information search speed
S4	0.53	-0.27	Indifferent	Data download speed
HP1	0.87	-0.48	One-Dimensional	Application front page display
HP2	0.70	-0.30	Attractive	Menu structure and display
HP3	0.65	-0.26	Attractive	Application features
HP4	0.87	-0.31	Attractive	Application interface design
K1	0.89	-0.33	Attractive	Application content suitability
K2	0.60	-0.31	Attractive	Application usage information
U1	0.50	-0.20	Indifferent	User communication space
U2	0.89	-0.26	Attractive	User-friendly application
U3	0.82	-0.25	Attractive	Service interaction quality
R1	0.83	-0.32	Attractive	Easy-to-read information
MD1	0.67	-0.36	Attractive	Data consistency between books and the system
A1	0.87	-0.28	Attractive	Sharp and reliable scan results
PP1	0.82	-0.25	Attractive	Accessibility via smartphone
PP2	0.83	-0.30	Attractive	Android operating system
LP3	0.33	-0.20	Indifferent	Application services and complaints
H2	0.33	-0.20	Indifferent	Interaction with app developers

Source: Research Result (2025)

Based on the data presented in Table 2, most attributes categorized as attractive exhibit relatively high Satisfaction Index (SI) values, indicating that these features play a significant role in enhancing user satisfaction. Features related to application usability, content suitability, and interface design contribute strongly to positive user experiences, suggesting that their presence adds substantial value even though they are not explicitly expected by users. The Dissatisfaction Index (DI) values for these attributes are still moderate, which means that their absence only causes minor dissatisfaction. This is in line with the characteristics of Attractive attributes in the Kano Model. In contrast, the one-dimensional attribute demonstrates both a high SI value and a relatively strong negative DI value, reflecting a linear relationship between feature performance and user satisfaction. This implies that improvements in this feature directly increase satisfaction, whereas performance degradation may result in dissatisfaction. Meanwhile, indifferent attributes show relatively low SI and DI values, indicating that changes in their performance have minimal impact on user satisfaction. Overall, these results suggest that attractive attributes have the most dominant influence on user satisfaction and should be prioritized in the development of the augmented reality library application.

These findings are consistent with previous studies showing that attractive attributes play a dominant role in shaping user satisfaction by providing added value beyond users' basic expectations. Studies conducted by Pinem et al. (2024) and Li and Xiao (2020) report that such attributes tend to generate high levels of satisfaction even though they are not explicitly demanded by users. In addition, research by Perangin-angin and Sihotang (2023) demonstrates that one-dimensional attributes exhibit a proportional relationship between system performance and user satisfaction, indicating that improvements or declines in performance directly influence user perceptions.

Meanwhile, Grosche (2025) notes that indifferent attributes generally have a neutral impact on satisfaction, although they may still contribute to interface refinement and overall system coherence. Furthermore, previous studies by Hidayat and Sulastri (2023) as well as Kuo and Chen (2021) highlight the effectiveness of the Kano Model in helping developers prioritize features with strong emotional and experiential impacts on users. Accordingly, the results of this study suggest that the developed augmented reality library application has met user expectations, as most of its features fall into categories that contribute positively to interactivity and ease of use.

7. System Development Implications
   This study yields several important implications for system development:

- Attractive features such as 3D display and voice interaction should be maintained as they significantly contribute to user satisfaction.
- One-Dimensional attributes such as marker detection speed can be optimized through algorithm improvements and device efficiency.
- Indifferent attributes can be developed into additional features such as book recommendations or digital catalogs.
- Integrating the system with user analytics will expand the application's benefits and enhance the user experience.

These results support Alzahrani's (2024) research, which states that the application of the Kano Model in digital system design increases user satisfaction and acceptance levels.

CONCLUSION

This study concludes that the integration of UML-based system design and the Kano Model is effective for developing and evaluating an augmented reality–based library application that supports interactive book searching and enhances user satisfaction. The implementation results indicate that most application features fall into the Attractive and One-Dimensional categories, highlighting their contribution to improving user experience and information retrieval in the university library context. Nevertheless, several limitations should be acknowledged, including the involvement of a limited number of respondents from a single study program, the focus of system testing on marker-based AR performance under normal lighting conditions, and the reliance on the Kano Model as the sole evaluation approach. These limitations restrict the generalizability of the findings and the depth of usability insights obtained. Therefore, future research is encouraged to involve more diverse user groups, evaluate system performance across varied devices and environmental conditions, and incorporate additional usability evaluation methods, as well as explore markerless AR technology, to obtain a more comprehensive understanding of user experience and system adaptability in library environments.

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