SculptMate: Personalizing cultural heritage experience using fuzzy weights

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ABSTRACT

Virtual Environment (VE) technology has become increasingly popular in the cultural heritage field, providing new ways to experience and interact with cultural artifacts and sites. By creating immersive and realistic virtual environments, VE technology allows users to explore and engage with cultural heritage in a more dynamic and engaging way. Towards this direction, this study introduces SculptMate, a cutting-edge mobile application that uses advanced personalization features (fuzzy logic) to enhance the appreciation and understanding of sculptures from various eras and artistic styles. The application aims to provide users with an immersive and interactive experience, both within and beyond museum settings, by allowing them to explore and interact with an extensive collection of virtual sculptures from museums and galleries worldwide. The paper's objectives are to investigate the potential of SculptMate, examine the effectiveness of fuzzy logic in personalizing the user experience, and assess the impact of the personalized experience on user engagement and satisfaction. The novelty of this study lies in the utilization of fuzzy logic in VE for personalizing the cultural heritage experience. SculptMate has been evaluated with very promising results.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **Interaction paradigms**; • **Virtual Environment**;

KEYWORDS

Cultural heritage, personalization, fuzzy logic, virtual models

UMAP '23 Adjunct, June 26–29, 2023, Limassol, Cyprus

ACM ISBN 978-1-4503-9891-6/23/06.
https://doi.org/10.1145/3563359.3596667

ACM Reference Format:
Panagiotis Strousopoulos, Christos Papakostas, Christos Troussas, Akrivi Krouska, Phivos Mylonas, and Cleo Sgouropoulou. 2023. SculptMate: Personalizing cultural heritage experience using fuzzy weights. In *UMAP '23 Adjunct: Adjunct Proceedings of the 31st ACM Conference on User Modeling, Adaptation and Personalization (UMAP '23 Adjunct), June 26–29, 2023, Limassol, Cyprus.* ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3563359.3596667

1 INTRODUCTION

Over the years, human civilization has witnessed a burgeoning interest in experiencing and interacting with various art forms, including sculptures from diverse historical periods and artistic styles [1]. This spectrum of creative expression ranges from ancient civilizations and extends to modern and contemporary works. At the same time, museums and galleries have increasingly embraced digital technologies to provide visitors with new ways of engaging with their collections, enhancing the overall experience, and broadening access to art. Mobile applications, in particular, can be such an example and potentially create an immersive and personalized experience for users inside and outside the museum setting, transcending traditional barriers of time and place [2-3].

Analyzing the related literature, there have been numerous systems and applications for art enjoyment and instruction, utilizing digital technologies like augmented reality, virtual reality, and artificial intelligence. Some include capabilities that are powered by Artificial Intelligence (AI) to improve learning and facilitate user interactions [2], [4]–[13]. Despite the significant strides made by these applications in promoting art appreciation and understanding, a gap still remains in explicitly addressing the appreciation of sculptures from various eras and styles. Instead of concentrating on the unique characteristics and requirements of engaging with sculptures, many applications encompass a broader range of art forms. This gap underscores the need for a more focused approach, which this paper aims to fulfill by honing in on sculptures and utilizing advanced personalization features. This technology allows continuous adaptation and refinement of content based on user interactions, creating a more engaging and tailored user experience.

The current study focuses on developing and evaluating SculptMate, a cutting-edge mobile application that enables users to interact with different 3D sculpture models. Artists made these digital sculptures in museums and galleries all over the world. The ancient, medieval, Renaissance, baroque, neoclassical, and modern periods are all represented by them artistically. To personalize the user experience, SculptMate continuously learns from users' preferences and interactions with the virtual sculptures. Users may adapt the content to their interests by liking or disliking particular statues, making the experience more engaging and enjoyable.

The paper's primary objectives are to:

- Investigate the potential of SculptMate as an innovative tool for enhancing the appreciation and understanding of sculptures from various eras and artistic styles through an immersive and interactive mobile application, both within and beyond museum settings.
- Examine the effectiveness of fuzzy logic in personalizing the user experience based on their preferences and interactions with the virtual sculptures.
- Assess the impact of the personalized experience on user engagement and satisfaction.

The concept of SculptMate originates from the convergence of multiple factors that have contributed to a shift in how art is experienced and appreciated by people in today's fast-paced, digitally connected world. The widespread adoption of smartphones and other mobile devices has created new opportunities for exploring art and connecting with cultural heritage [5]. The visualization technology improvements have made it feasible to produce precise and realistic digital reproductions of sculptures, enabling impossible virtual interactions with real-world objects [14]. Additionally, the rapid advancement of technology has created new opportunities for analyzing and forecasting user behavior, creating completely customized experiences catered to each user's tastes and interests [2], [5], [8], [15], [16].

SculptMate aims to offer a unique and fascinating platform for art appreciation that uses these technological advances by using the synergies between mobile technology, 3D modeling, and artificial intelligence. The application incorporates several crucial components and features to accomplish this, such as:

- A 3D model viewer that allows users to explore and interact with an extensive collection of virtual sculptures from museums and galleries worldwide, representing diverse historical periods and artistic styles.
- A fuzzy logic engine that analyzes user interactions to refine the personalization algorithm and enhance the user experience continuously. By monitoring the users' likes and dislikes and other behavioral data, the engine adapts its recommendations to ensure the content remains relevant and engaging. The fuzzy logic engine receives input from a preference-based filtering system (PbFS), enabling users to like or dislike sculptures and receive personalized recommendations based on their preferences. This feature encourages users to engage with the content actively and helps them discover new sculptures that align with their interests.

The paper is structured as follows. Section 2 provides an overview of SculptMate's architecture and delves into the details of its components. Section 3 focuses on content personalization in SculptMate, with sub-sections discussing fuzzy weights, describing the decision-making process, and presenting an example of operation. Section 4 outlines the evaluation methodology and the specific instruments used to collect participant data, followed by the evaluation results and the effectiveness and potential of SculptMate. Finally, Section 5 offers concluding remarks, identifies limitations and suggests future research and development directions.

2 ARCHITECTURE AND OVERVIEW OF THE SYSTEM

SculptMate's architecture is designed to provide users with an immersive experience while interacting with 3D models of sculptures from various eras and artistic styles. Thanks to the architecture, a high level of usability and adaptability is maintained while ensuring that the application performs optimally across multiple devices. The user interface (UI) layer provides an aesthetically pleasing and interactive environment, the application logic layer is in charge of integrating features, functionalities, and personalization into the system, and lastly, the data storage layer, where the 3D models and user preferences are stored; the aforementioned are the three main layers that form the SculptMate's architecture (Figure 1). SculptMate is a distinctive and ground-breaking tool for art appreciation and education because these layers work together to produce an engaging and personalized user experience.

In more detail, the user interface layer acts as SculptMate's visual and interactive front end, giving users access to a visually appealing and simple-to-navigate environment. This layer's simplicity and usability-focused design make it possible for users with different levels of the smartphone experience to interact with the app effectively. The UI employs modern design principles and leverages native mobile platform components to offer a responsive and visually appealing experience. Key elements of the interface include a 3D model viewer for exploring, rotating, and zooming into sculptures and preference buttons for content personalization. By offering a user-centric interface that is both engaging and accessible, the UI layer plays a critical role in shaping the overall user experience in SculptMate.

The SculptMate application user interface design, conceived with a focus on simplicity, ensures that individuals from all age brackets can intuitively navigate and utilize the application efficiently. From the outset, our mission was to construct an interface that seamlessly marries straightforwardness with user-friendliness yet upholds the full spectrum of intended functionality. Our user interface is designed with each element carefully designed to facilitate user interaction. Users can explore the app's vast selection of sculptures with only a few clicks, making it pleasant for new and experienced users. The simple yet effective approach we designed for users to show their admiration for a particular sculpture is one of the interface's significant features. This system uses like and dislikes prominently displayed buttons. Users can effortlessly convey their preference toward a sculpture with a simple press.

The application logic layer constitutes the core of SculptMate, integrating the various features and functionalities and ensuring seamless communication between the user interface and data storage layers. This layer manages user inputs, coordinates the 3D

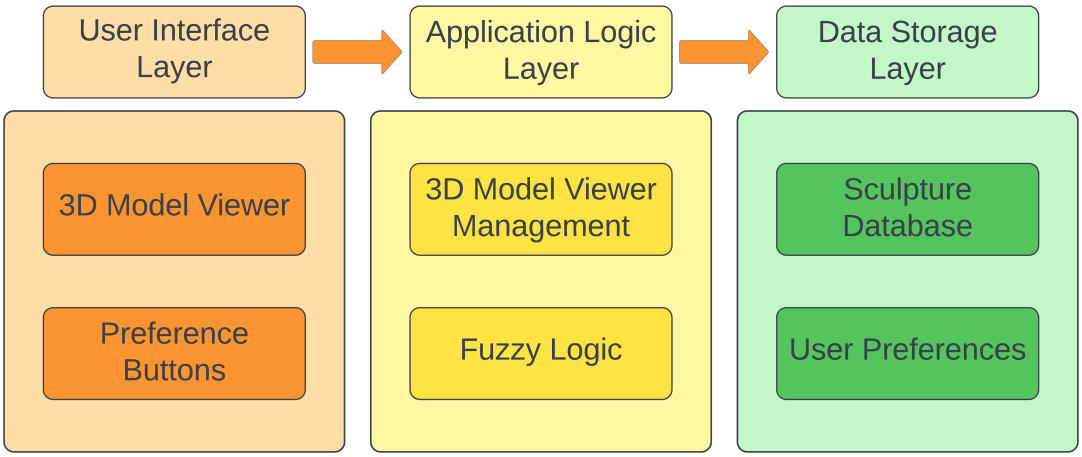

Figure 1: SculptMate architecture

model viewer functionalities such as rotation and zooming, and implements the preference-based filtering system. Additionally, it interfaces with the fuzzy logic for personalization, refining content recommendations based on user interactions. Furthermore, a mode is available for users with a compatible headset, allowing them to view the 3D models in a more immersive virtual environment. The application logic layer is developed using a modular approach, enabling easy maintenance and updates of individual components without disrupting overall functionality. This layer also serves as the central hub for processing and managing the built-in 3D model data and associated information about the sculptures, ensuring that the app remains accurate and effective.

The data storage layer of SculptMate is designed to provide a solid foundation for the application by housing the complete 3D models, user preferences, and fuzzy logic-driven recommendations. Given the absence of a server or cloud-based storage, SculptMate relies on local storage on the user's device for all its data needs. This includes storing user preferences, likes, and dislikes and caching frequently accessed data to enable faster load times and a more fluid user experience. The extensive collection of 3D models and associated metadata is also stored locally, ensuring the data is securely housed and accessible even without an internet connection. The data storage layer is carefully designed to optimize performance, and data integrity, making it an integral part of SculptMate's overall architecture.

SculptMate's architecture combines the user interface, application logic, and data storage layers to create a unique, immersive, personalized art appreciation experience. By focusing on usability, adaptability, and performance, the architecture ensures that SculptMate remains accessible and engaging for diverse users while offering a rich platform for exploring sculptures. This architectural design contributes to SculptMate's success as an innovative mobile application. It sets the stage for future enhancements and expansion, such as incorporating server-based storage, integrating APIs to access a broader range of 3D models and resources, or adding functionality for users to share their preferences with others. This would foster a more connected community and enable users to discover new sculptures and styles through social engagement, further enriching the SculptMate experience.

3 CONTENT PERSONALIZATION

3.1 Fuzzy Weights

In the context of SculptMate about the history of sculpture, fuzzy weights are used to create an enhanced personalized experience by taking into account multiple factors when tailoring the user's experience. The application asks the users to rate their interest in different eras of sculpture, such as Renaissance, Baroque, or Modern. Using fuzzy weights, the application then uses these ratings to determine which sculptures to highlight during the user's virtual tour. The user's ratings are also combined with other factors, such as the popularity of different sculptures among other users, to further tailor the experience. Overall, using fuzzy weights in a mobile application about the history of sculptures allows for a more nuanced and personalized experience that considers multiple factors to tailor the user's journey through the museum.

SculptMate uses six fuzzy sets to represent different sculpture periods, making it a useful approach in creating a personalized virtual environment experience about the history of sculpture. The fuzzy weightings that define the users' sculpture period of interest are the foundation of the SculptMate student model. The six parties involved reflect on how well each of the subsequent six fuzzy sets represents the user's current period of interest:

- Ancient sculpture (AS): (prehistory - 550CE) - focused on the idealized depiction of the human form, often in religious or civic contexts. It was characterized by the development of the classical styles of Ancient Greece and Rome, which emphasized naturalism, symmetry, and proportion and had a lasting influence on Western art;
- Medieval sculpture (MS): (500 CE-1400 CE) - influenced by the religious traditions of Christianity and Islam, Medieval sculpture was characterized by stylized, symbolic depictions of religious figures and motifs. It often served a functional

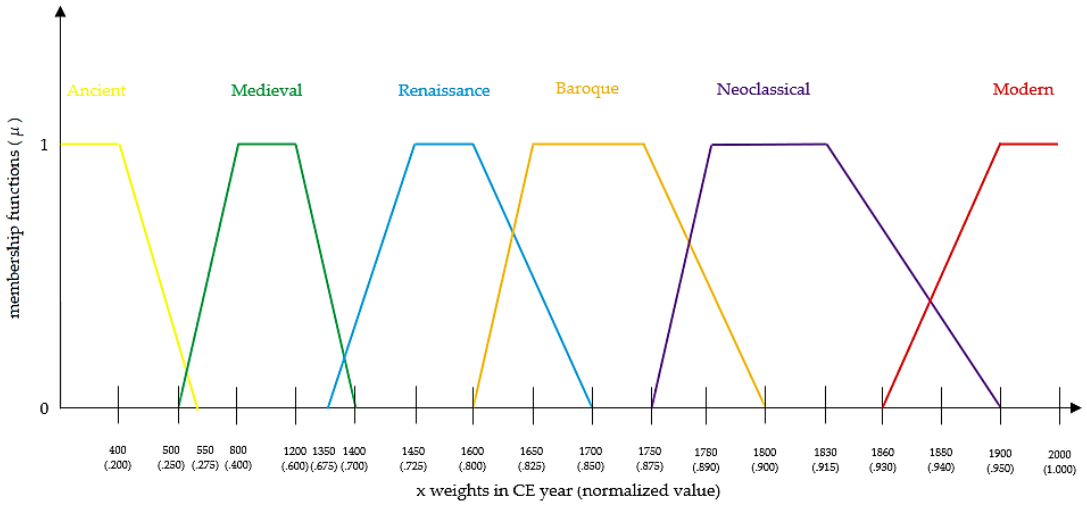

Figure 2: Linguistic scales and fuzzy weights numbers of sculpture period

purpose in the context of religious worship and featured a wide range of materials and techniques, from wood and stone carving to metalworking and enamel;

- Renaissance sculpture (RS): (1350 CE - 1600 CE) - the Renaissance marked a renewed interest in classical art and culture. Renaissance sculpture focused on realistic depictions of the human form and the use of perspective and proportion to create lifelike and dynamic compositions. Sculptors such as Michelangelo, Donatello, and Bernini created some of the most iconic works of Western art during this period, and their influence can still be seen in sculpture today;
- Baroque sculpture (BS): (1600 CE - 1750 CE) - Known for its grandeur, dynamism, and theatricality, Baroque sculpture emphasized emotional expressiveness and dramatic movement, often depicting religious or mythological scenes. Baroque sculptors experimented with new materials, such as stucco and gilded bronze, and created works that were designed to impress and awe viewers;
- Neoclassical sculpture (NS): (1750 CE - 1830 CE) - Inspired by the art and culture of ancient Greece and Rome, Neoclassical sculpture favored simplicity, clarity, and balance, often depicting heroic or idealized figures in a classical style. Sculptors such as Antonio Canova and Jean-Antoine Houdon created works that were highly prized for their technical skill and artistic refinement;
- Modern sculpture (MoS): (1850 CE - present) - has embraced a wide range of artistic styles and movements, from the abstract and avant-garde to the figurative and representational. Artists such as Pablo Picasso, Constantin Brancusi, and Louise Bourgeois have pushed the boundaries of sculpture, exploring new materials, techniques, and forms and challenging our assumptions about what sculpture can be.

Utilizing the following membership functions, the sextet that describes the user's interest period is calculated. A trapezoidal function is used to express the boundary values for each of the mentioned fuzzy weights, which vary from 0 to 1 (Figure 2).

Using these fuzzy sets, the SculptMate application asks the user to rate their interest in each period and then use fuzzy weights to determine which sculptures to highlight during the user's virtual tour. For example, suppose the user is intensely interested in the Renaissance period. In that case, the application focuses on sculptures from that period and provides more detailed information about them in the audio guide. Overall, using fuzzy sets to represent different sculpture periods is a useful way to create a personalized virtual experience that takes into account the user's interests and preferences.

The degree of membership scales from 0 to 1 before flattening out and dropping to 0 at the end. The flattened portion of the trapezoidal function clearly demonstrates that the student's score (x) belongs to the designated group. The fuzzy weights membership functions are shown in Figure 3.

The user's period of interest is determined by six fuzzy sets (AS, MS, RS, BS, NS and MoS), varying from 0 to 1. According to the membership functions presented in Figure 3, a user's rating of 1918 equals $\mu_{AS}(x)=0$, $\mu_{MS}(x)=0$, $\mu_{RS}(x)=0$, $\mu_{BS}(x)=0$, $\mu_{NS}(x)=0$ and $\mu_{MoS}(x)=1$, meaning that the sextet (0, 0, 0, 0, 0, 1) indicates the user is 100% interested in the modern period of sculpture.

3.2 Decision Making

Experts in a variety of fields within sculpture found value in utilizing fuzzy weights and related thresholds at membership functions, depending on their specific area of expertise and the nature of the problems they are trying to solve.

More specifically, two art historians, who have a deep understanding of the history and evolution of sculpture, used fuzzy logic techniques to analyze and classify sculptures based on various criteria such as style, period, and material. Two sculptors and artists utilized fuzzy weights and membership functions to make decisions about multiple aspects of the creative process, such as the selection

$$\mu_{AS}(x) = \begin{cases} 1; & x \le .200 \\ 1 - \dfrac{x - .200}{.075}; & .200 \le x \le .275 \\ 0; & x \ge .275 \end{cases}$$

$$\mu_{MS}(x) = \begin{cases} \dfrac{x - .250}{.150}; & .250 \le x \le .400 \\ 1; & .400 \le x \le .600 \\ 1 - \dfrac{x - .600}{.100}; & .600 \le x \le .700 \\ 0; & x \le .250 \text{ or } x \ge .700 \end{cases}$$

$$\mu_{RS}(x) = \begin{cases} \dfrac{x - .675}{.05}; & .675 \le x \le .725 \\ 1; & .725 \le x \le .800 \\ 1 - \dfrac{x - .800}{.050}; & .800 \le x \le .850 \\ 0; & x \le .675 \text{ or } x \ge .850 \end{cases}$$

$$\mu_{BS}(x) = \begin{cases} \dfrac{x - .800}{.025}; & .800 \le x \le .825 \\ 1; & .825 \le x \le .875 \\ 1 - \dfrac{x - .875}{.025}; & .875 \le x \le .900 \\ 0; & x \le .800 \text{ or } x \ge .900 \end{cases}$$

$$\mu_{NS}(x) = \begin{cases} \dfrac{x - .875}{.015}; & .875 \le x \le .890 \\ 1; & .890 \le x \le .915 \\ 1 - \dfrac{x - .915}{.035}; & .915 \le x \le .950 \\ 0; & x \le .875 \text{ or } x \ge .950 \end{cases}$$

$$\mu_{MoS}(x) = \begin{cases} \dfrac{x - .930}{.02}; & .930 \le x \le .950 \\ 1; & x \ge .950 \\ 0; & x \le .930 \end{cases}$$

Figure 3: Fuzzy weights membership functions

of materials or the choice of form and style. Two museum curators and conservators are responsible for the care, preservation, and display of sculptures in museums and other institutions. Finally, two art educators are accountable for teaching students about the history and techniques of sculpture.

In this section, the analysis of the rules in combination with the fuzzy weights to adapt the content of the provided sculptures to the users' interests [17], [18]. The aforementioned experts have defined the rules, and the set of the rules in total is represented in Table 1.

Figure 4: Example of a delivered 3D model of the Modern sculpture period

3.3 Example of Operation

According to the aforementioned rules, a user interested most in modern sculpture has been classified at the twelfth fuzzy set, as the values of $\mu_{AS}(x)$, $\mu_{MS}(x)$, $\mu_{RS}(x)$, $\mu_{BS}(x)$, $\mu_{NS}(x)$ and $\mu_{MoS}(x)$ are 0, 0, 0, 0, 0 and 1 respectively. The delivered 3D models of the sculptures will be none of the Ancient, Medieval, Renaissance, Baroque, and Neoclassical, while 10 sculptures will be delivered from the Modern period, as shown in Figure 4.[1]

Specifically, Figure 4 shows a famous sculpture of Giannoulis Chalepas (1851-1938), a Greek sculptor considered one of Greece's most important modern artists of the 19th century. He is known for his highly emotional and expressive works, influenced by his

[1] Chalepas' Sleeping Girl, freely accessible at the First Cemetery, Athens, Attica, Greece

Table 1: Decision rules for adaptive content

Classification of period	Ancient	Medieval	Renaissance	Medieval	Neoclassical	Modern
$\mu_{AS} = 1$	10	0	0	0	0	0
$\mu_{AS} < 1$	8	0	0	0	0	0
$\mu_{MS} < 1$	0	8	0	0	0	0
$\mu_{MS} = 1$	0	10	0	0	0	0
$\mu_{RS} < 1$	0	0	8	0	0	0
$\mu_{RS} = 1$	0	0	10	0	0	0
$\mu_{RS} < 1$ and $\mu_{BS} < 1$	0	0	5	6	0	0
$\mu_{BS} = 1$	0	0	0	10	0	0
$\mu_{BS} < 1$ and $\mu_{NS} < 1$	0	0	0	5	6	0
$\mu_{NS} = 1$	0	0	0	0	10	0
$\mu_{NS} < 1$ and $\mu_{MoS} < 1$	0	0	0	0	6	5
$\mu_{MoS} = 1$	0	0	0	0	0	10

struggles with mental illness. In Figure 4, it is presented his most widely known sculpture, namely the "Sleeping Female Figure". It was created in marble for the grave of eighteen-year-old Sofia Afentaki in the 1st Cemetery of Athens. The sculpture was created by Chalepas in 1877 and a cast of the sculpture was made in 1980 in the workshop of the National Archeological Museum.

3.4 3D Scanning

To digitize the tangible aesthetics of classical sculptural art, we undertook the three-dimensional (3D) scanning of the "Sleeping Female Figure," the magnum opus of Chalepas. Initially conceived in marble for the resting place of an eighteen-year-old woman, in the 1st Cemetery of Athens. This sculpture has long been recognized as a profound embodiment of mourning and serenity.

The scanning process was executed using an iPhone 13 Pro Max, leveraging LiDAR capabilities. The scanning application utilized was Scaniverse, an app renowned for its robust functionality and fidelity in capturing high-resolution 3D models. The LiDAR sensor, embedded within the phone, functioned as the cornerstone of this endeavor, enabling us to map the sculpture's detailed contours and intricate textures with exceptional precision.

The scanning procedure required a systematic and unhurried approach. We started by positioning ourselves at a reasonable distance from the sculpture to capture its overall structure and gradually moving closer, allowing the LiDAR to register the finer details of the masterpiece. As we navigated around the sculpture, we maintained a slow, consistent pace, ensuring the LiDAR had ample opportunity to accurately capture every dimension and aspect of the "Sleeping Female Figure". The process demanded a 360-degree exploration of the artwork. We circumambulated the sculpture multiple times, constantly varying our angles and elevations to ensure every facet was recorded. We aimed for comprehensive coverage, from the sculpture's base to its apex, front to back, and every gradient in between.

Scaniverse's real-time feedback was instrumental in this process, allowing us to observe and fill in any missed details or gaps. The scan was a meticulous fusion of technology and patience, gradually layering point upon point of LiDAR data to construct a digital twin of the Chalepas' masterwork, faithful to the original in form and detail.

Following the thorough scanning process, the next stage of our endeavor involved refining the digital replica using Blender, an open-source 3D creation suite acclaimed for its flexibility and powerful toolset. The raw LiDAR data, although comprehensive, needed further refinement and perfection to mimic the original sculpture more closely. Importing the 3D model into Blender, we meticulously examined the scan, identifying any discrepancies and imperfections that may have arisen during the scanning process. We focused on geometric inaccuracies, artifacts, and surface irregularities, common challenges in 3D scanning procedures. Using Blender's versatile toolset, we methodically smoothed surfaces, enhanced details, and fixed any inconsistencies in the raw model to ensure that our digital representation reflected the physical dimensions of the sculpture accurately.

4 EVALUATION RESULTS

To validate the effectiveness and potential of SculptMate, the application was subjected to a rigorous evaluation process involving a diverse group of participants, including 50 undergraduate 2nd-year university students interested in art. Age and gender measurements were all derived from a randomly selected group and had no impact on the study's findings. The demographic analysis is shown in Table 2.

The evaluation process was designed to address the following key aspects:

User engagement: Assess the extent to which SculptMate promotes active engagement with the content and fosters a deeper appreciation and understanding of the featured sculptures.

Personalization effectiveness: Determine the accuracy and relevance of the personalized recommendations generated by the fuzzy logic engine based on user preferences and interactions.

User satisfaction: Consider users' satisfaction with the features and user interface and note any areas that can be improved.

The authors conducted interviews with the students to gather information about the application's features, utilizing a full explanation of the system's design as the framework for the conversation.

Table 2: Demographics

Measure	Item	Frequency	Percentage (%)
Sample size		50	100.0
Gender	Male	32	64.0
	Female	18	36.0
Age	18-19	34	68.0
	20-21	9	18.0
	Over 22	7	14.0
Level of VE knowledge	None	6	12.0
	Medium	36	72.0
	Advanced	8	16.0
Motivation	All students were interested in art and cultural heritage		

After evaluating the system and its guiding plan, the users submitted their suggestions to the authors. These recommendations included suggestions on how to enhance the design of the system in particular manners as well as recommendations on how to improve the tour process overall.

The questions asked to evaluate the user's interface were the following:

- Question 1 (Q1): To what extent does the SculptMate application presents high-quality 3D objects?
- Question 2 (Q2): Has the SculptMate application good functionality?
- The questions asked to evaluate the system's effectiveness were the following:
- Question 3 (Q3): Are users more likely to engage in the system in order to navigate and learn more about their sculpture period of interest?
- Question 4 (Q4): How effective was the system regarding the delivery of content adapted to your personal interests in sculpture?

For the user interface, the first question (Q1) aims to evaluate the quality of the 3D objects presented in the SculptMate application. The answers to this question helped the authors assess whether the 3D objects are visually appealing and realistic, which are important factors for user engagement and satisfaction. A positive response to this question indicates that the system has a high-quality user interface.

The second question (Q2) focuses on the functionality of the SculptMate application. The answers to this question provided the authors' insights into how easy it is for users to navigate through the system, how intuitive the controls are, and whether the system offers enough features to meet the users' needs. A positive response to this question indicates that the system has good functionality and a user-friendly interface.

In terms of system effectiveness, the third question (Q3) aims to assess whether users are more likely to engage with the system to navigate and learn more about their sculpture period of interest. A positive response to this question suggests that the system effectively provides users with relevant and engaging content and that the interface is designed to encourage user engagement.

The fourth question (Q4) focuses on the delivery of content that is adapted to the user's personal interests in sculpture. The answers to this question helped the authors evaluate whether the system effectively provides personalized content and whether the users find the content interesting and relevant to their interests. A positive response to this question suggests that the system is effective in providing personalized content that meets the users' needs.

Overall, these questions provide a useful framework for evaluating the user interface and effectiveness of the SculptMate application. The answers to these questions helped in identifying areas where the system is performing well and areas where improvements can be made to enhance the user experience and effectiveness of the system.

Analyzing the answers to the aforementioned questions, we present the results of the first two questions in pie charts (Figures 5-6). The Likert scale type of rating was used in our survey research to measure the students' opinions. Specifically, a 5-Likert scale format was used, rating the following response options: 1. strongly disagree; 2. disagree; 3. neither agree nor disagree; 4. Agree, and 5. strongly agree. For reporting purposes, Figures 6-9 present low, fair, and high groups the response options as follows: low presents the strongly disagree and disagree options, fair groups neither agree nor disagree, while high groups the agree and strongly agree answers.

Analyzing the answers to the questions regarding the system's effectiveness, we present the results of the last two questions in pie charts (Figures 7-8). They also present the results using a 5-Likert scale format, utilizing the same grouping of low, fair, and high values with their corresponding response options.

Participants were asked to score their overall satisfaction, user engagement, and personalization efficacy after using SculptMate for a specified time. To learn more about user behavior and preferences, the researchers also gathered usage information from the application, such as the number of sculptures viewed, liked, and disliked, and the time spent on each. 99% of the sculptures integrated into the SculptMate application received a "Like" according to the system's log files, this information indicates that the users of the application generally have a positive attitude toward the sculptures. The evaluation's findings were very positive and showed that SculptMate has the potential to be a creative and valuable tool for fostering a greater awareness and knowledge of sculptures from diverse historical periods and artistic movements. Participants reported high levels of engagement with the content, frequently discovering new sculptures that matched their interests and expressing a desire to

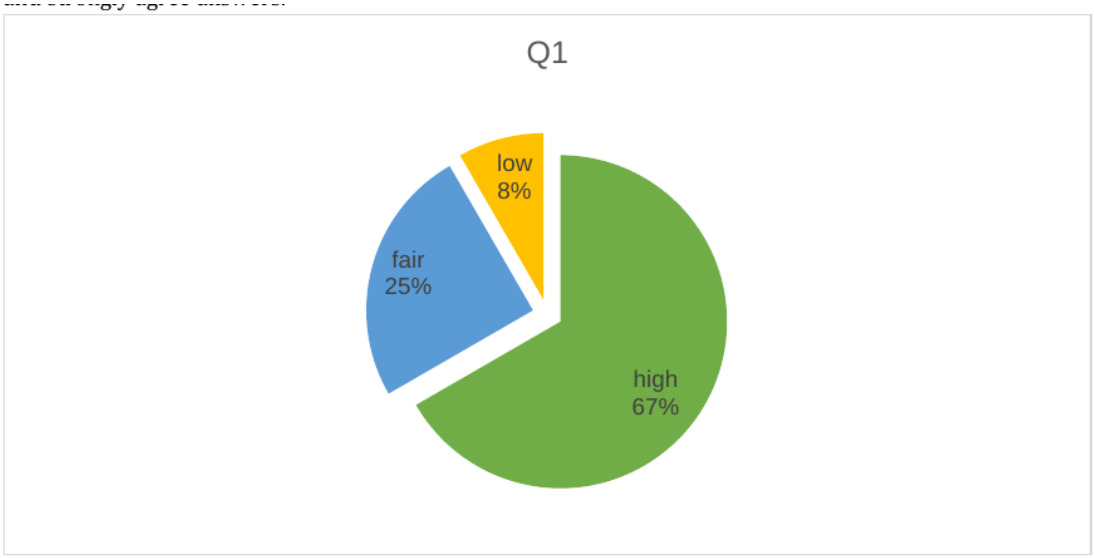

Figure 5: Results of the 1st question regarding the user interface

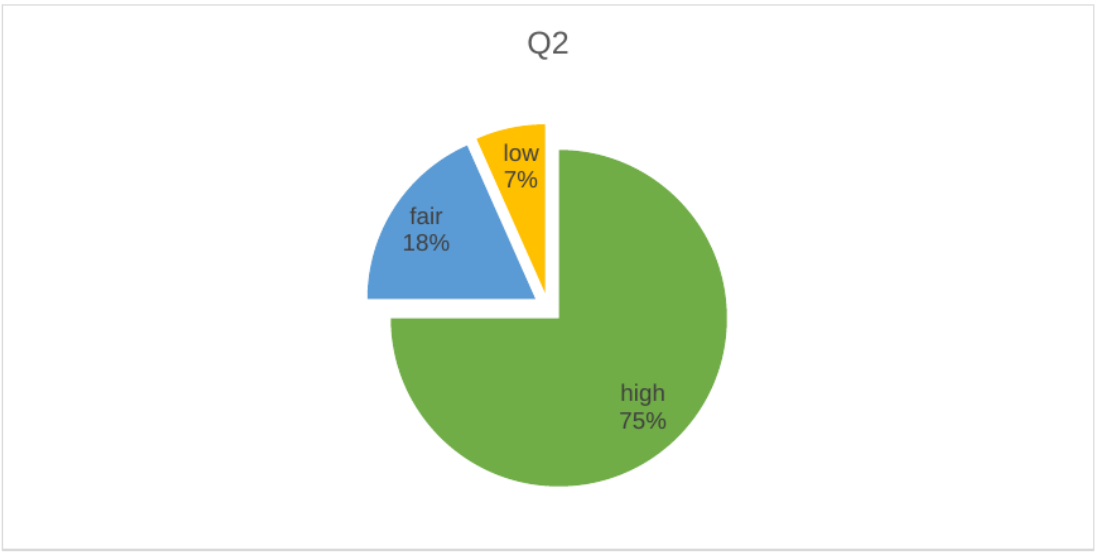

Figure 6: Results of the 2nd question regarding the user interface

learn more about the featured artworks and their historical context. The personalized recommendations generated by the fuzzy logic engine were found to be accurate and relevant, effectively adapting to the users' preferences and interactions with the virtual sculptures. Overall, users expressed high satisfaction with the application, praising its intuitive interface, rich content, and immersive experience.

Furthermore, a *t*-test was used to assess the statistical significance of the findings and answer the research questions, and the results are presented in Tables 3-6. We compared the performance of two groups: an experimental group (namely Group A) that received the personalized approach utilizing the fuzzy logic component of the system and a control group (namely Group B) that did not. The goal of the t-test was to determine if there was a significant difference between the two groups or if any observed differences could be attributed to chance fluctuations.

The null hypothesis was that the means of the two groups were equal (Condition 0), while the alternative hypothesis was that they were not (Condition 1). The *t*-test was used to calculate the *p*-value, which indicates the probability of observing the differences between the two groups by chance, and a significance level of alpha=0.05 was used to determine the statistical significance of the results.

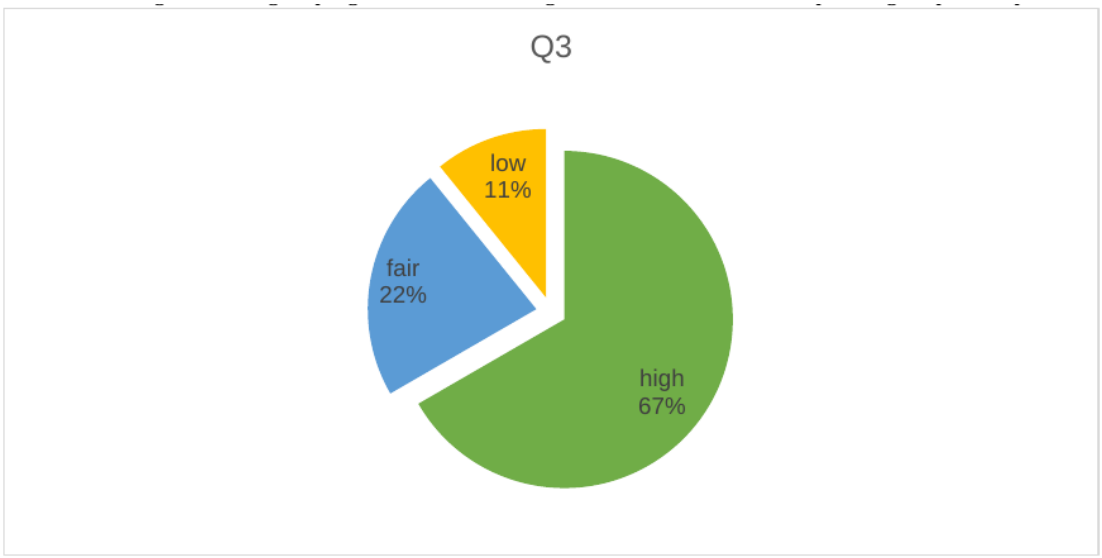

Figure 7: Results of the 3rd question regarding the user interface

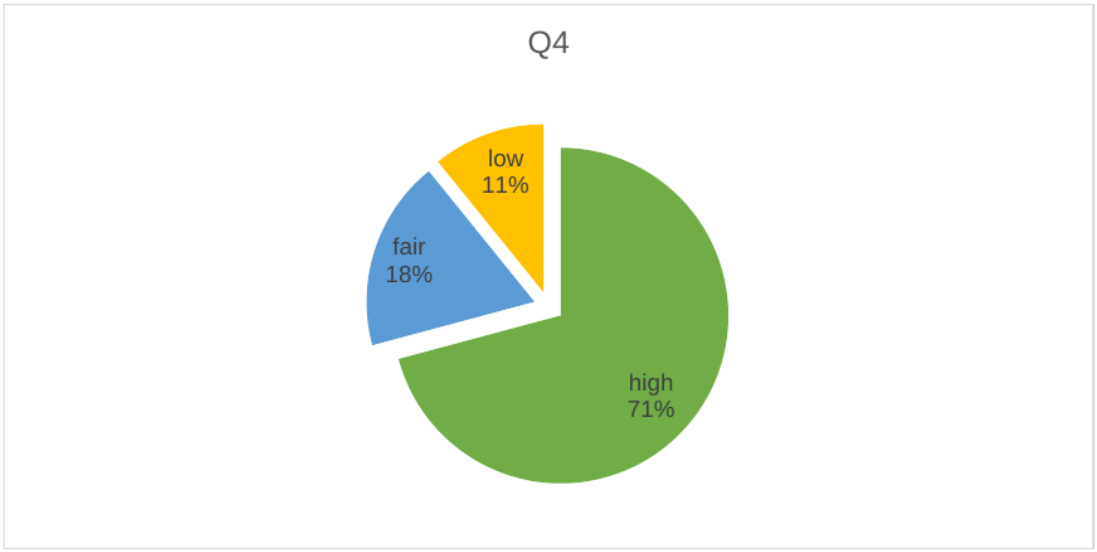

Figure 8: Results of the 4th question regarding the user interface

The 50 participants who took advantage of the fuzzy logic algorithm ($M = 4.132$, $SD = 0.353$) compared to the 50 participants in the control group ($M = 3.082$, $SD = 0.836$) demonstrated significantly better peak flow scores in the first question, $t(211) = 13.700$, $p<0.05$ (Table 3). The 50 participants of the experimental group ($M = 4.025$, $SD = 0.398$) compared to the participants of group B ($M = 2.879$, $SD = 0.991$) also demonstrated significantly better peak flow scores in the second question, $t(199) = 11.600$, $p < 0.05$ (Table 4). In the third question, the participants of Group A ($M = 4.271$, $SD = 0.249$) compared to the participants of Group B ($M = 3.109$, $SD = 0.751$) showed noticeably higher peak flow scores, $t(218) = 10.300$, $p<0.05$ (Table 5). Finally, the participants of the experimental group ($M = 4.008$, $SD = 0.449$) compared to the participants of the control group ($M = 2.882$, $SD = 0.993$) also demonstrated significantly better peak flow scores in the fourth question, $t(205) = 12.300$, $p < 0.05$ (Table 6).

According to the results, the experimental group performed significantly better than the control group in all four questions, with p-values less than 0.05. These findings suggest that the fuzzy logic approach had a significant impact on the experience of the experimental group, and the observed differences in performance between the two groups are unlikely to have occurred by chance.

Table 3: *t*-Test results of the 1st question

	Group A	Group B
Mean	4.132	3.082
Variance	0.353	0.836
Observations	50	50
Hypothesized Mean Difference	0	
Df	211	
t Stat	13.700	
P (T<=t) one-tail	<0.001	
t Critical one-tail	1.342	
P (T<=t) two-tail	<0.001	
t Critical two-tail	1.792	

Table 4: *t*-Test results of the 2nd question

	Group A	Group B
Mean	4.025	2.879
Variance	0.398	0.991
Observations	50	50
Hypothesized Mean Difference	0	
Df	199	
t Stat	11.600	
P (T<=t) one-tail	<0.001	
t Critical one-tail	1.567	
P (T<=t) two-tail	<0.001	
t Critical two-tail	1.823	

Table 5: *t*-Test results of the 3rd question

	Group A	Group B
Mean	4.271	3.109
Variance	0.249	0.751
Observations	50	50
Hypothesized Mean Difference	0	
df	218	
t Stat	10.300	
P (T<=t) one-tail	<0.001	
t Critical one-tail	1.462	
P (T<=t) two-tail	<0.001	
t Critical two-tail	1.554	

Table 6: *t*-Test results of the 4th question

	Group A	Group B
Mean	4.008	2.882
Variance	0.449	0.993
Observations	50	50
Hypothesized Mean Difference	0	
Df	205	
t Stat	12.300	
P (T<=t) one-tail	<0.001	
t Critical one-tail	1.239	
P (T<=t) two-tail	<0.001	
t Critical two-tail	1.883	

5 CONCLUSIONS

In this paper, SculptMate is presented, which is a mobile application that aims to enhance the appreciation and understanding of sculptures from various eras and artistic styles through an immersive and interactive experience. This study investigates the potential of SculptMate as an innovative tool for art appreciation and examines the effectiveness of fuzzy logic in personalizing the user experience based on their preferences and interactions with virtual sculptures. The impact of the personalized experience on user engagement and satisfaction is also assessed.

SculptMate incorporates several crucial components, such as a 3D model viewer that allows users to explore and interact with an extensive collection of virtual sculptures from museums and galleries worldwide, representing diverse historical periods and artistic styles. A preference-based filtering system enables users to like or dislike sculptures and receive personalized recommendations based on their preferences, while a fuzzy logic engine continuously adapts its recommendations to ensure the content remains relevant and engaging.

One significant benefit of VE technology in cultural heritage is its ability to provide access to sites and artifacts that may be difficult to visit or have limited access due to preservation or safety concerns. For example, VE can allow users to explore ancient ruins, visit historical buildings, and even travel back in time to experience historical events.

Moreover, VE technology can also provide a more comprehensive understanding of cultural heritage by enabling users to see and interact with artifacts and sites in their original context. This technology can also provide insights into the history, architecture, and cultural significance of these artifacts and sites.

The study uses a mixed-methods approach to evaluate the effectiveness and potential of SculptMate. The results indicate that SculptMate is an effective tool for enhancing the appreciation and understanding of sculptures and that the fuzzy logic engine significantly improves the user experience. Users reported high levels of engagement and satisfaction with the personalized recommendations and the overall user experience.

SculptMate represents an innovative and promising approach to art appreciation that utilizes advanced technologies, such as mobile devices, 3D modeling, and artificial intelligence (fuzzy logic), to provide users with an immersive and personalized experience.

It needs to ne noted that all the 3D models integrated into the SculpMate are displayed in public spaces, they are freely accessible to the public, and they are not subject to copyright or intellectual property protections. In many cases, many cultural artifacts and sites are subject to copyright, which can make it challenging to create accurate 3D models without permission from the rights holders. In some cases, the rights holders may be the original creators of the

artifact, while in other cases, the rights may have been acquired by a third party, such as a museum or government agency. In case the rights holders do not grant permission to create 3D models, it is difficult or impossible to create accurate and detailed representations of the artifacts or sites. Furthermore, even if permission is granted, there may be limitations on how the 3D models can be used and shared.

There are possible directions for future work in the field of art and technology, specifically in the context of SculptMate. More specifically, while SculptMate currently provides access to an extensive collection of sculptures from different eras and artistic styles, there is still room for expansion. Future work could focus on adding more sculptures to the collection, including those from lesser-known artists and regions. Obtaining permission to digitize and create 3D models of sculptures displayed in museums would be an important area of future work. Many museums have extensive collections of sculptures, ranging from ancient artifacts to modern works of art. By creating accurate 3D models of these sculptures, the research could gain new insights into the history, culture, and artistic styles of different periods and regions. Lastly, SculptMate's personalization features could be further improved by incorporating more sophisticated algorithms and machine learning techniques. For example, the application could learn from users' interactions with other art-related content, such as videos and articles, to provide even more tailored recommendations.

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