360° Virtual Reality Video Tours Generation Model for Hostelry and Tourism based on the Analysis of User Profiles and Case-based Reasoning

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***Abstract*—This paper proposes an adaptive software architecture focused on hotel marketing based on immersive virtual reality (VRI) with 360° videos, which includes a component based on Case-Based Reasoning (CBR) to provide experiences that correspond to the analysis of user profiles. For the validation of the system, considering that the use of VR can trigger experiences in several dimensions, affective, attitudinal and behavioral responses, as well as the cognitive load were evaluated using visualizations of 2D photographs contained in hotel websites , which were compared with 360° videos in a VRI environment. To test the hypotheses, a quasi-experimental study was conducted with an independent sample group, in which subjects were randomly assigned to the two types of visualizations. The contribution of the article lies in the incorporation of marketing concepts and approaches in VRI experiences with 360° videos through virtual objects that are used by the software architecture, as well as in the proposed validation of the effectiveness of the proposal.**

***Keywords*—Immersive virtual reality; adaptive software architecture; case-based reasoning; user profiles**

I. Introduction

Making visits to tourist resorts, hotels, museums, laboratories, factories, etc. in tourist, hotel and educational environments through virtual tours mediated by 360° immersive virtual reality (IVR) devices can become an important factor for the success of marketing strategies used by hotel, tourist, educational and other organizations.

VR employs virtual scenarios that allow the user to move freely in the virtual environment, while 360° VR offers spherical/panoramic experiences [1]. Immersive 360° video became popular in contemporary applications due to a higher perceived credibility in those scenarios, considering that 360° VR content is based on real-world photos and videos, which can be more representative of the environment the experience is focused on [2], allowing to offer a clearer and more detailed vision of the environment and a more pleasant experience [3]. Wu and Lin [4] consider that VR environment can be directly linked to 360° videos, impacting the perception-sensation of presence.

This work is focused on the proposal of a system model that performs the division of 360° videos, to then make the composition of tours, considering an intelligent component based on Case Base Reasoning (CBR) that adapts and performs the composition of tours according to the specific requirements of each user profile, which will be displayed as 360° virtual reality videos tours.

For the implementation of the CBR component, some data related to potential guests, such as the area of the hotel, the reason for the trip, whether they will travel accompanied, the services they require from the hotel and the priority they give to each of these services, are considered in the inputs for the CBR algorithm, which obtains the cases from a database based on the information of previous guest visits.

Wan, Tsaur, Chiu, and Chiou [5] suggest that when using VR as a resource for promotion, the context and specific details of the objectives should be considered, because results may vary and a one-size-fits-all approach should be avoided, as there are reported differences in the effectiveness and impacts of VR [6]. In this perspective, cognitive load, affective aspects and behavioral outcomes were identified as factors to be considered when comparing visualizations using VR resources with traditional ones [7]. In order to validate the effectiveness of the proposed model, it is investigated whether the visualization of 360° VR video tours can outperform the visualization of 2D photos used by traditional marketing resources, which is still under study.

Several studies were focused on the evaluation of the content and functions of hotel web sites, based on online satisfaction of consumers. For [8], the content of the website and its functions can directly influence the preferences and decisions of customers. Website functionalities represent the completeness of a website and its features [9], considering a list of hotel website functionalities, whose classification establishes four dimensions [10]: general hotel information, referring to the mechanism through which a hotel introduces products and services to potential consumers; reservation information, referring to the functions and information about the hotel room to be reserved, website management and surrounding information, referring to online services and features that help hotels communicate with potential consumers.

Website usability design is used to determine the experience and interaction of consumers on hotel websites [11], [12]. Au Yeung and Law [13] conducted a usability study adopting a heuristic model, which considered the following aspects: navigability, ease of use of the website, the number of languages available [14]. Consumers' online satisfaction is influenced by the ease of navigating web pages for information search and that a good user-friendly system of a website leads to a positive first impression. The users are always looking for the website quality and quality of hotel services [15].

The previous studies were focused on establishing a comprehensive evaluation of websites both of the functionality and the usability criteria to establish the general usefulness performance of a hotel website, being necessary also to explore and evaluate the influence of the adaptability of tours in hotel facilities and services to the requirements of user profiles, as well as the objective of determining the cognitive, affective and attitudinal responses, in the exploration of hotel web sites, in order to demonstrate whether for the visualization of hotel environments and services, the use of 360°VR whose technical knowledge requirements and costs are lower than those of immersive VR applications, can be more powerful in making users feel influenced in relation to booking the hotel and/or or say positive things to other potential users compared to 2D images.

The following is a description of the points discussed in the different sections. Section II reviews the literature, Section III presents the proposed software model and the use of the CBR engine for the proposed model, Section IV establishes the methodology, Section V describes the tests and discusses the results, and finally, Section VI establishes the conclusions and recommendations for future work.

II. Review of the Literature

A. Immersive Virtual Reality Technologies (VRI)

A well known definition definition of VR is: "the use of a computer-generated 3D environment in which the user can navigate and interact, resulting in a real-time simulation of one or more of the user's five senses" [16]. As [17] argue, solutions focused on tourism applications can be non-immersive, semi-immersive and fully immersive, and when a solution is more immersive, the more complicated and complex is the implementation of the technology, devices and content.

Significant improvements in VR technologies impacted more frequent use in tourism research and practice [18]. Various authors divide VR applied in tourism into five categories: planning and management, education, marketing, accessibility, heritage conservation, and entertainment. This paper is specifically focused on marketing in tourism and hospitality. Several authors focused on the similarities and differences between VR and augmented reality (AR) [19]. Other authors focused on VR as a visualization technique in which the real environment completely disappears and the client is immersed in a completely digital world [20]. Other authors state that mixed reality (MR) describes the combination of a real environment with digital content, and can vary perceptions of the real environment without complete virtual immersion [21].

From a hardware perspective, a virtual environment represents a "digital space" in which a user's movements are tracked and their environment rendered, and displayed through various senses, according to those movements [22]. A virtual environment makes it possible to replace the real-world environment by allowing users to block out the physical world of stimuli and fully immerse themselves in the virtual world [23]. The emergence of smartphones and online virtual environments allowed marketing experts to engage tourists as active participants in VR applications, where destinations can be experienced from the comfort of their home [24].

VR technologies, properly used in the proposed adaptive model, which have Artificial Intelligence components, provide an immersive interaction, which is focused on the characteristics and interests of users, which should be framed in the concepts of Experiential Marketing and Sensory Marketing, for the adaptation of experiences and virtual objects in a personalized way and according to the experiences offered by a particular hotel and in a particular environment.

B. 360° Videos in Virtual Immersion

The use of 360° videos is relevant from the use of VR technology to create immersive spaces in which the observer mimics, captures through the senses and feels what has been artificially created in the environment. According to [25], immersive videos show more interesting information within the 360° environment than normal videos and are more eye-catching, due to the greater interest of users in those visual contents, since there is a feeling of being present in the explored content; in addition, that information of interest to explore can be obtained, that is why the number of consumers in the entertainment industry using 360° videos is increasing day by day.

The system includes a perceptual component, coupled with the technological component, which generates in the viewer the illusion of being in another place, despite knowing that this is not real, as highlighted in [26]. The narrative receives particular attention because it has been shown that the deliberate manipulation of the narrative structure affects the phenomenon called "transportation" of the reader or viewer, as mentioned in [27]. The "theory of narrative transportation" [28] describes an experience by which the reader or viewer "disappears" in the narrative worlds through the commented theory.

In [29], it is proposed that immersion should generate a sensation similar to when one is immersed in the ocean: of being surrounded by a completely different reality. In [30], an emphasis is placed on the narrative with the proposal that immersion is a different mental process, an integrative mixture of images, feelings and attention, where the participant's attention and capabilities are focused on the events occurring in the narrative. In that direction, the type of narrative required for virtuality must rethink the current narrative structures, as proposed in [31] and [32]. In [26] it is argued that, in order to rethink the narrative structure, it is necessary to manage the space in such a way that, through it, the viewer perceives the sensation of being immersed in the reality proposed in the 360° video; considering the technology on which the narrative is based. A satisfactory answer to the change of narrative structure has not yet been achieved. The research for this topic focuses on improving the production of 360° videos, which is a challenging path to undertake.

In relation to these VR resources, according to [33] several authors, two dimensions are defined as the virtual presence of the observer, the media or technological characteristics of the system (media form) and the content of that system (content factors); the latter includes the objects, actors or events represented in the narrative.

C. User Profiles

Understanding what users want to get from the services they use is important, as it can facilitate the offer of different personalized content [34], it is important to evaluate the behavior of users and generate personalized profiles, based on the data obtained, resulting in valuable knowledge for the content creator; additionally, it can allow the possibility of including advertisements or interactive advertising, for example, in the form of questionnaires; but this will not be useful only as an advertising campaign, but can also be a means to collect valuable information about a brand or product, and to support decisions in future marketing actions.

D. Case-Based Reasoning (CBR)

The basic concepts of CBR can be presented as follows: a so-called "base case" is generated, which is a problem question that will be compared with previous cases; for this purpose, a similarity function is used to recognize the possibility of adaptation between the new case and the existing cases in the case base. As a result, the most matching case is selected and this solution will be considered as a suggested solution to the new case. The three steps involved in CBR are:

1) Step 1: Build a case base. For greater accuracy, the complete case base will be accessed.

2) Step 2: Implement a similarity function. The implementation of this function will depend on the experience and logic of the developer. This function must be able to recognize the degree of similarity between the new case and the cases stored in the case base.

3) Step 3: Find the most similar cases and choose the best ones, according to the adaptation criteria.

The degree of similarity between attributes is multiplied by a weight factor, which represents how much that attribute influences the search, and then the sum of the similarity of all the attributes is calculated to obtain an overall measure of the similarity of the case [35]. In this way, we can obtain the percentage of similarity with which it is possible to sort the list of cases that have been previously stored, so we can deduce that the system will be constantly learning and improving.

In [36], it is mentioned that the CBR allows a great capacity for learning and adaptation to the context, since it resorts to past experiences to solve similar problems, as well as to generate creative solutions to new problems. Each time a new user enters to consult about tours that he/she wants to visualize, the probability of finding a visual resource that is useful to him/her increases, so that, thanks to this approach, we can prepare our system for future searches that have not been taken into account due to the great amount of variety that may exist in the preferences of the users.

E. Adaptive Systems in Marketing

For adaptive marketing systems, there are several sources of experience, such as Intelligent Learning Environments (ILE), Tutorial Systems (ITS) [37], Pedagogical Agents (PA) [38], and Adaptive e-Learning systems [39], [40], whose characteristics and adaptation techniques can contribute to achieve experiences and present virtual objects in adaptive marketing systems, according to the profiles, characteristics and expectations of potential hotel guests, improving their exploration and learning activities about hotels. In [41], it is mentioned that it is possible to generate first-person experiences related to the facilities and services provided by a hotel, through information exploration techniques and VR.

In [42] it is pointed out that these systems have as an important feature the ability to adapt the interaction process and the virtual objects, which must be flexible to the specific requirements and profiles of the users. The characteristics of the user must be considered for decision making, elements that constitute a key factor for the success of its development and implementation.

This approach was reviewed in several works [43], which recommend adaptations focused on Cognitive Styles (CS), to which it is convenient to adapt virtual experiences and objects, which resemble the contact with the hotel facilities or services. In [44] it is mentioned that the adaptation to the client's knowledge consists of focusing on the adaptation of the objects to be explored and the presentation of contents, according to the client's knowledge on the subject, about the facilities, services, experiences, landscape, environment, etc. The adaptability of marketing systems is one of the important factors to improve their quality and efficiency.

This work is focused on identifying the adaptability parameters of content and virtual objects for each particular hotel customer and then using a CBR for the adaptation of virtual experiences and objects. All these issues and elements explored have allowed the establishment of the proposed model.

Regarding the gaps and limitations of the related works, it was possible to verify that most of them focus on the usability, interactivity and functionality tests of the applications, but few studies analyze the cognitive load, which could influence the results of the tests and analyzes carried out.

III. Software Architecture Proposal

To provide a better experience to users using the proposed immersive application, a CBR engine was used to provide tour recommendations to potential users, based on user preferences and previous stored experiences, either from the user's own queries or from other users with similar profiles. In this way, if a user is interested in a certain service, they will be shown tours that have that service and fit their requirements.

Within the CBR, each case corresponds to an experience or query previously made. These cases are derived from legacy databases, converting organizational resources into exploitable knowledge. Within the proposal, the cases will be stored when a user decides to view one of the tours offered.

The attributes that make up each case, defined on the basis of the data most commonly used by hotel companies are:

- Id: tour identifier in the database, which will be used to show the recommendations to the user.
- Zone: main characteristic of the area where the hotel is located, for example, near the beach or in the city.
- Reason: represents the reason for the user's trip, e.g., vacation, work.
- Services: represents the services the hotel has; essential to show certain images or 360° videos when viewing a tour.

TABLE I. Table of Attribute Weights

Attribute	Weight
Zone	15%
Motive	24%
Services	17%
Company	20%
Priority	24%
TOTAL	**100%**

- Company: indicates whether the user is traveling alone or with other people (family, friends, partner, etc.).
- Priority: the most important criterion for the user when choosing a hotel, for example, price.

Six parameters are defined for the CBR search function:

- Attribute names: represents the attributes of the case to be taken into account at the time of the search.
- Search values: represents the search case, which will be the basis for searching for those cases that are most similar to it.
- Weights: importance of each attribute in the search, which allows the CBR to prioritize the attributes. These weights were obtained based on the opinions of experts in hotel management, marketing, researchers, and potential users, as shown in Table I.
- Terms: defines how each attribute will be searched, for example: equal, greater, close values, etc.
- Scales: represents how the difference between the cases and the search case will be searched mathematically, for example: linearly, logarithmically, etc.
- Search options: defines how the search results are sorted, the default option being to return the closest values.

The result of the search is a list of cases that, due to the proposed implemented configuration, will first display in the immersive application interface the cases that are most similar to the base tour, as recommendations, considering the preferences that were entered previously.

After the search, if the user enters one of the recommended tours, a new case is created in the case base, with the information stored in the user's profile, allowing to increase it, which will serve to make recommendations closer to the user's needs and preferences in future searches.

A. *Proposed Architecture*

For the development, the 4+1 architecture view model was selected, since it allows describing the system architecture using multiple concurrent views [45], as shown in Fig. 1. The views describe the system from the point of view of the main stakeholders, such as end users, developers, and researchers.

The proposed model consists of four components, where the intelligent component is responsible for adapting to the characteristics and needs of customers, which requires the identification and knowledge of the characteristics of the hotel, its services and its environment, which will be represented in virtual objects, which must be provided to the customer, according to their characteristics and interests.

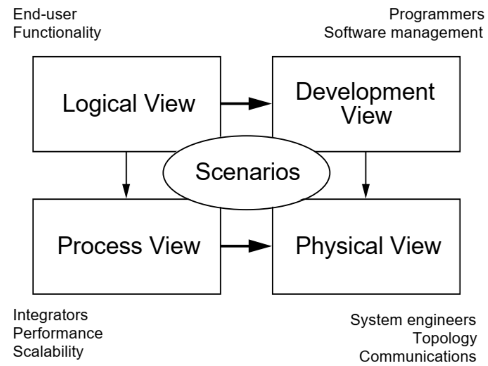

Fig. 1. Proposed Architecture. Source: Own Elaboration.

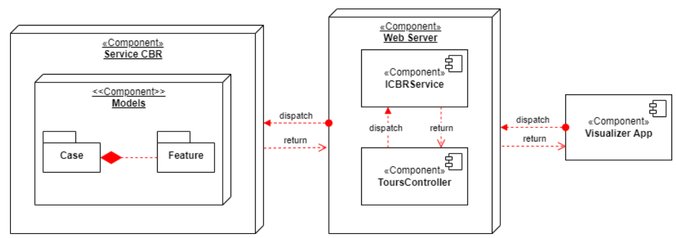

Fig. 2. Development View. Source: Own Elaboration.

The application uses the client-server model, where the server is responsible for transmitting hotel and tour information to customers through the immersive application, and for collecting tour recommendations through the CBR.

B. *Development View*

The development view is shown in Fig. 2, and considers three main components: the server, the intelligent layer (CBR) and the visualization layer (immersive application). The connection between these components is based on HTTP requests that are originated by the application when the user searches for tour recommendations. The server receives the request and connects to the CBR, which returns the response of the recommendations, using the case and feature models, where a case can be composed of several features.

C. *Process View*

The process view in Fig. 3 presents the three most important actors: the application, the server, and the intelligent layer (CBR). The process checks if the user's preferences are saved. If they are not, or if they need to be updated, a form will be displayed and the data entered by the user will be saved. If the data is already stored and does not need to be updated, this step is skipped, and the list of recommended tours obtained from the CBR is sent.

D. *Physical View*

The view shows the interconnection between the web server and the immersive application, as shown in Fig. 4.

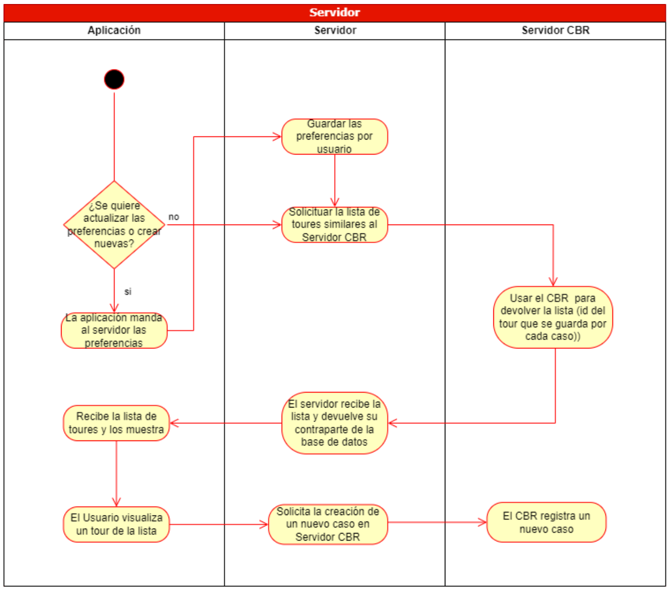

Fig. 3. Process View. Source: Own Elaboration.

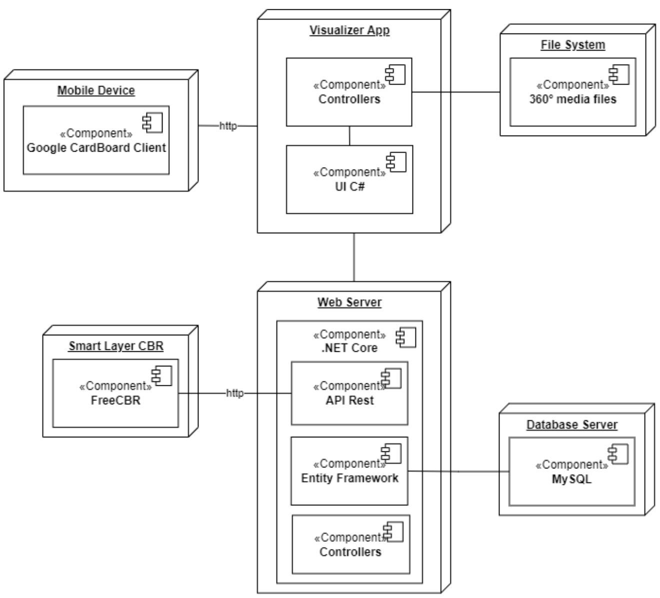

Fig. 4. Physical View. Source: Own Elaboration.

The view presents five components, the web server that uses the CBR through an API and obtains the tour information through a database connection, using Entity Framework; the client that uses the connection with the web server to show the recommended hotels and tours to the user, and obtain the 360° images/videos. The intelligent layer connects to the server and only interacts with it. The application is not aware of the existence of this component.

E. Logical View

Fig. 5 shows the four main classes present in the intelligent layer: CBRController, Case, CBR, and Feature. The intelligent layer exposes a Rest API; its main controller is CBRController, whose methods expose two endpoints: getCases, to return the list of tours related to the input tour, and addCase, to register new cases.

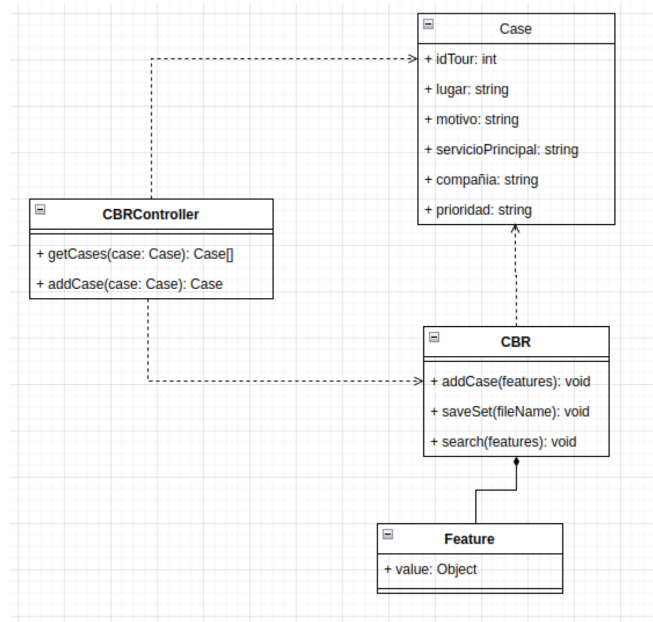

Fig. 5. Logical View. Source: Own Elaboration.

The CBRController class works with the Case class, which is a POJO that stores the attributes mentioned in section III. Along with this class, the CBR class is used, where the CBR cases will be converted to the Case class for its use since the CBR class works with an array of Feature instances, allowing a more comfortable handling of the CBR.

IV. Methodology

A. Model Development Methodology

For the development of the model, a methodology based on seven stages was followed:

1) Requirements and user story gathering with hotel managers.
2) Design of the customer journey map and analysis of the guest experience by management and marketing specialists.
3) Capture of 360° images and videos in test hotel establishments.
4) Design and prototyping of immersive application user interfaces.
5) Implementation of the visualization layer as an immersive application in Unity, targeting VR glasses.
6) Implementation of the intelligent layer, based on an RBC engine and a Rest API.
7) Functionality testing, based on test cases, and validation testing, based on the TLX-NASA method.

The operation of the CBR starts with the generation of a new search request for tour recommendations, based on the entry of a new case containing the following data: destination zone, reason for the trip, required services, company, and priority in the search.

The CBR configuration defines the terms, scales and weights for the search of recommendations. For this, each case is evaluated by independently comparing each of its attributes. Then, a total value (hit) will be displayed for each case, which represents the distance in the search space, and is used as an indicator of the similarity of the case. The lower the value, the greater the similarity to the search case, i.e., a hit of 0.0 translates as identical cases. At the end of the evaluation of all the cases, a list ordered by similarity will be returned, according to the hit value, eliminating the identical cases in order not to repeat results, and the information obtained from the CBR can be used.

The web server uses the list of tour IDs to retrieve the tour information to display and recommend to the user. If the user decides to view one of the recommended tours, it is considered to match the user's interests, so the search parameters and the selected tour are stored as a new case in the CBR, allowing it to be used in subsequent searches, and to obtain greater precision in future recommendations within the immersive application.

For the validation of the CBR, the case library subset test (CLST) technique, proposed by [46], is used, where the main idea is to select a subset of the case library and use this subset to evaluate the effectiveness of the recovery and adaptation functions of the system. For this purpose, the validation criterion is defined, which consists of two parameters:

- Result Acceptability Criteria (RAC): The maximum acceptable relative error of the solution compared to the standard. A RAC of 15% has been defined.
- System Validity Criteria (SVC): Threshold value to determine whether, after running and evaluating the subset of cases, the system can be considered valid. The percentage of accepted cases must be greater than this value. An SVC of 75% has been defined.

A total of 50 cases were used for the retrieval and adaptation tests under the CLST technique. The results obtained from the tests are shown in Table II.

After the tests were performed, 100% acceptance was obtained in the recovery tests, and 88% in the adaptation tests, so the proposed CBR model is considered valid, according to the SVC (75%).

TABLE II. CBR TEST RESULTS

N°	Recovery	Result	Adaptation	Result
1	100.00	Success	100.00	Success
2	100.00	Success	100.00	Success
3	100.00	Success	100.00	Success
4	100.00	Success	100.00	Success
5	100.00	Success	100.00	Success
6	100.00	Success	61.27	Failed
7	100.00	Success	100.00	Success
8	100.00	Success	61.27	Failed
9	100.00	Success	100.00	Success
10	100.00	Success	61.27	Failed
11	100.00	Success	100.00	Success
12	100.00	Success	100.00	Success
13	100.00	Success	100.00	Success
14	100.00	Success	100.00	Success
15	100.00	Success	100.00	Success
16	100.00	Success	100.00	Success
17	100.00	Success	100.00	Success
18	100.00	Success	100.00	Success
19	100.00	Success	100.00	Success
20	100.00	Success	100.00	Success
21	100.00	Success	100.00	Success
22	100.00	Success	100.00	Success
23	100.00	Success	100.00	Success
24	100.00	Success	100.00	Success
25	100.00	Success	100.00	Success
26	100.00	Success	86.26	Success
27	100.00	Success	86.26	Success
28	100.00	Success	86.26	Success
29	100.00	Success	86.26	Success
30	100.00	Success	86.26	Success
31	100.00	Success	100.00	Success
32	100.00	Success	100.00	Success
33	100.00	Success	100.00	Success
34	100.00	Success	100.00	Success
35	100.00	Success	100.00	Success
36	100.00	Success	100.00	Success
37	100.00	Success	56.13	Failed
38	100.00	Success	100.00	Success
39	100.00	Success	51.01	Failed
40	100.00	Success	100.00	Success
41	100.00	Success	100.00	Success
42	100.00	Success	56.13	Success
43	100.00	Success	100.00	Success
44	100.00	Success	100.00	Success
45	100.00	Success	100.00	Success
46	100.00	Success	100.00	Success
47	100.00	Success	100.00	Success
48	100.00	Success	100.00	Success
49	100.00	Success	100.00	Success
50	100.00	Success	100.00	Success

B. Methodology for Validating the Effectiveness of the Model

The literature review on consumer behavior establishes that affective, cognitive and attitudinal responses are important elements in understanding consumer habits, the decision-making process and ultimately predicting user behavior. The specific research question to validate the results obtained with the architecture is:

How do traditional photo and video displays compare to 360o video displays in VR applications, in terms of (1) cognitive load, i.e., task and experience efforts associated with the technology? (2) affective responses, and (3) attitudinal/behavioral responses.

VR can trigger experiences in several dimensions, such as cognitive, affective, sensory, attitudinal and behavioral [7]:

1) Cognitive CLT Response [47]: and the limited perceptual capacity model of attention [48] give a theoretical framework for comprehension the processing of Virtual Reality visualizations. Virtual Reality hotel images will be associated with greater cognitive/perceptual load than traditional forms of imagery, and the next hypotheses are established:

Hypothesis 1a: 360° VR video visualizations of hotel en-

vironments and services will not elicit higher cognitive load compared to traditional photo and video visualizations of the similar scenes.

Hypothesis 1b: 360° VR video visualizations of hotel environments and services will elicit higher cognitive load compared to traditional photo and video visualizations of the similar scenes.

2) Affective Response: Many studies have found that VR experiences provoke emotional responses or conditions, like a galvanic skin response, skin conductance, increased heart rate, blood pressure and respiration [49], because VR engages the senses at an increase intense level, it generate an intense affective response compared with the traditional imagery. The immersive nature of VR, the intensified presence and sensory stimulation become a intense emotional experience. In addition, VR tends to be conducive to evoking a wide range of affective responses, such excitement, arousal, as general emotions of frustration, and pleasure [50]. For that reason, it is logical to assume that hotel VR 360° videos would evoke affective responses, which may be stronger relative to traditional photos and videos. As a result, the next hypotheses are established:

Hypothesis 2a: 360° VR video displays of hotel environments and services will not evoke stronger affective responses compared to photo and 2D video displays of the similar scenes.

Hypothesis 2b: VR 360° video displays of hotel environments and services will evoke stronger affective responses compared to photo and 2D video displays of the similar scenes.

3) Attitudinal and Behavioral Responses: Knowledge on how 360° videos in Virtual Reality affect customer behaviors and attitudes remains insufficient, particularly in tourism and hospitality [51]. Van Kerrebroeck et al. [52] report that consumers had more positive attitudes, satisfaction, and loyalty after being exposed to the VR experience in the mall context.

Studies by Choi and Taylor [53] and Stoyanova et al. [54], propose that sense of presence and representational richness (relevant to Virtual Reality) can produce more positive consumer attitudes towards a brand, as well as higher purchasing intentions.

Based on that assumption, the next hypotheses are established:

Hypothesis 3a: 360° VR video displays of hotel environments and services will not evoke more positive attitudinal responses compared to photo and 2D video displays of the same scenes.

Hypothesis 3b: 360° VR video displays of hotel environments and services will evoke more positive attitudinal responses compared to photo and 2D video displays of the same scenes.

Hypothesis 4a: VR 360° video displays of the hotel surroundings, environments, and services will not evoke stronger behavioral responses compared to photo and 2D video displays of the same scenes.

Hypothesis 4b: VR 360° video displays of the hotel surroundings, environments, and services will evoke stronger behavioral responses compared to photo and 2D video displays of the same scenes.

TABLE III. RELIABILITY STATISTICS

Cronbach's alpha	Cronbach's alpha based on standardized elements	Number of elements
.830	.832	10

The procedure established is the next: All measurement items keep out demographic information were adopted from another studies.

For affective responses to the visualizations received, the Pleasure, Arousal, and Dominance (PAD) scale [55], widely validated in some studies measuring affective response to colors and physical environments [56], can be used. The scale begins with a statement, "After visualizing the images of the hotel, I feel ..." followed by 18 bipolar items:

1) Pairs of pleasure-related adjectives: unhappy-happy, annoyed-pleased, dissatisfied-satisfied, depressed-content, despairing-hopeful, bored-relaxed.
2) Pairs of arousal adjectives: relaxed-stimulated, calm-excited, slow-frenetic, bored-nervous, sleepy-awake, unexcited-excited.
3) Pairs of adjectives related to dominance: controlled-controlling; influenced-influential; insignificant-important; submissive-dominant; restrained-free.

A 7-point semantic differential scale, from 1 to 7, can be used to assess each bipolar pair [56].

Attitudes and behavioral intentions toward hotels were measured through a 7-item scale adopted from Slevitch and Oh [57]. The measure includes attitudinal questions such as:

1) How likely would it be, that you would decide to book at the hotel you saw?
2) To what extent would you be satisfied with your decision to stay at that hotel?
3) Does the hotel you viewed match its price?

The behavioral questions are as follows:

1) How likely would you be to book such a hotel?
2) How likely would you be to say positive things about the hotel to others?

To measure cognitive workload, one of the most established tests is the NASA TLX, which assesses subjective mental workload [58], and is based on the cognitive demand of a task [59]. The NASA TLX assesses workload in six areas: mental demand, physical demand, temporary demand, performance, effort, and frustration, which are assessed using a differential scale. Its reliability and validity have been confirmed in several studies.

The Cronbach's alpha approach was applied to validate the consistency of the survey questions of both groups, obtaining the satisfactory results shown in the Table III.

A quasi-experimental study was conducted to test the hypotheses. The lobby of a boutique hotel and a beach hotel and various environments were captured in both 2D photos and videos, as well as 360° videos, which can be viewed through a PC and with an immersive helmet, respectively. Subjects were randomly assigned to two types of visualizations that serve as experimental conditions. The experiment took place in various locations and environments.

For the test case of videos in VR, the VR HMD device that allows immersive experiences based solely on smartphone was used to create an immersive virtual experience [60].

Participants are individually exposed to an experience and must be asked to imagine a situation in which they are choosing a hotel, considering one of the motivations established in the study, as well as a location. Cost was not considered. Subjects were then exposed to one of the experimental conditions for five minutes. Participants in the VR group received assistance in donning the devices and verbal permission was obtained from the participants to use their images in the study.

After receiving the experimental treatment, subjects were asked to fill out a questionnaire on Google forms. The duration of the trial was completed within one month.

V. Tests and Discussion of Results

The sample consisted of 312 potential customers, randomly selected from a population of 1620 users, composed of young people, including professionals, undergraduates and graduate and postgraduate university students. Tests 1 and 2 included an equal number of participants, 156 each. The analysis of the results is as follows:

A factor analysis restricted to the use of only three components was used to (1) establish the dimensionality of the PAD scale Pleasure, Excitement and Dominance - and (2) develop composite variables for based on the sum of values for each factor. Principal component analysis was used as extraction method and varimax with Kaiser normalization was applied as rotation method and the cut-off value of the correlation was 0.5. The factor analysis was adequate, based on Bartlett's sphericity test ($p < 0.0000$), and the KMO test (Kaiser-Meyer-Olkin), which yielded a statistic of 0.838.

A. Cognitive Load Answers

Test 1 and Test 2 produced responses with some differences for most items in the cognitive load component (see 2D Cognitive Dimension Table, available at [61]). Scores were significantly lower for Test 1 compared to Test 2 by 12.5% on the mental demand scale. There was a lower physical demand in 360° VRI visualization compared to 2D by 16.6%. There was also a lower temporal demand in 360° VRI visualization compared to 2D by 13.5%. Less effort was also found in 360° VRI visualization compared to 2D by 8.3%. The frustration level was slightly lower in 360° VRI compared to 2D by 4.2%.

B. Affective Answers

Test 1 and Test 2 produced responses with some differences for most items in the affective load component (see Affective Dimension 2D Table, available online [61]), as shown in the results, and statistically significant differences were identified, equivalent to 17%, with a larger difference observed for females. There was a statistically significant difference in responses between the visual conditions on how insecure, discouraged, irritated, stressed and annoyed respondents felt about the task. Scores were significantly lower for Test 1 compared to Test 2 by 4.9% on the Pleased-annoyed scale. The 360° VRI images scored lower compared to the scores produced in the 2D condition by -2.1% for the Animated-Abashed scale. Participants who viewed the 2D images scored higher compared to those exposed to the 360° VRI by 9.4% on the tense-relaxed scale.

C. Attitudinal and Behavioral Responses

There was a significant difference between the attitude responses for Test 2 data and a behavioral response in Test 1. Participants in Test 2D felt more positive about staying at the hotel compared to those exposed to 360° VRI images, with a difference of 29%. Participants exposed to 2D photos were more likely to book into the hotel compared to their 360° VRI counterparts by 25.9%. It can be inferred that at this point bookings would have higher preferences for 2D because the hotel's website allows access to information on all the hotel's environments and services, while 360° VRI visualizations could be accessed in a free way through hotspots, or by providing user profile data and displaying only information of interest, showing partial information on the hotel, so further studies are required to corroborate the results obtained.

D. Limitations and Further Research

The data to model and validate the architecture were collected in the city of Arequipa, considering potential hotel clients, as well as Master's in Marketing and undergraduate students from the National University of San Agustín, who may not have accurately reproduced world conditions. real and limit the external validity of the results. Therefore, the application of the results to the hotel industry must be done with caution. In future research, an effort should be made to design conditions that are similar to real world experiences.

The samples met the minimum size requirements, derived in part from the sanitary restrictions derived from the Covid-19 pandemic, but they may still be small. The study also included a limited scope of affective responses as only three dimensions were examined and other potentially relevant emotions were not considered. In the future, psychophysiological measures could be included in the studies to correct deficiencies that could have been caused by the self-reported measures and those that may not have been the best way to capture affectivity.

E. Discussion and Implications

The findings suggest that 360° VR visualizations differ from traditional 2D images only in some dimensions of cognitive load.

At the same time, VR users felt less insecure, discouraged, irritated, stressed and annoyed by the task at hand. Such findings suggest that various visual aspects and the complexity of visual details produce a variety of impacts on cognitive load and task performance.

Visuals of hotel environments and services displayed in 360° VR produced stronger affective responses compared to 2D visuals, with a larger difference for women. The possible explanation for the observed inconsistencies may lie in the fact that previous studies examined affective responses to VR in other contexts, such as gaming, food service, retail, etc. Gibson and O'Rawe [51] and Wan et al. [5] caution that the effects of RV may vary in different contexts; therefore, the ac-tual findings may point to peculiarities of the hotel context, which merit further investigation. Furthermore, the results might have been affected by weaknesses in self-reported measures when applied to affective responses. Self-reported measures are prone to cognitive biases and socially desirable responses and, more importantly, such measures are unable to capture respondents' unconscious affective reactions. It is also possible that, as explained, access to limited information through hotspot login or filtered by user profiles may have influenced attitudinal evaluation, and further studies with more complete information on 360° VRI are required.

The current study also produced evidence that VR images of hotel service layers may be more powerful in making users feel more positive about staying at the hotel and saying positive things about the hotel to other potential users compared to 2D images. The findings were not very consistent, indicating that further research is needed.

Regarding the challenges encountered, the use of 360° videos for immersive reality represents a great opportunity, given the low cost of display devices, which is why more empirical research is needed that can be used in other fields such as of hospitality, so that investments in this field get a good return on investment.

VI. Conclusion

An adaptive software architecture model based on hotel marketing concepts and strategies was proposed from 360° VRI videos and to validate the effectiveness of experiences with the model, 360° VRI visualizations were evaluated in comparison with 2D photographs. Since traditional 360° video immersion and 2D image viewing can trigger experiences in various dimensions, cognitive, affective, attitudinal, and behavioral loads were evaluated.

The results of the study suggest that 360° VR views differ from traditional 2D images only on a few dimensions of cognitive load. Also, 360° VR users felt less insecure, discouraged, irritated, stressed, and annoyed while performing viewing tasks, suggesting that visualizations and the complexity of visual details produce a variety of impacts on cognitive load and performance. task performance. Viewing hotel environments with 360° VR produced stronger affective responses compared to 2D visuals.

The study also found that 360°VR image displays of hotel environments and services may be more powerful in making users feel positive about booking the hotel and saying positive things to other potential users compared to 2D images. The findings were not very consistent, indicating that further research is needed to establish that investments in emerging technologies in hotel marketing are made based on a framework of adequate knowledge and experience.

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