IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received June 1, 2021, accepted June 21, 2021, date of publication July 1, 2021, date of current version July 15, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3093829

Spatial Augmented Reality Based Customer Satisfaction Enhancement and Monitoring System

UDAYA DAMPAGE, (Senior Member, IEEE), D. A. EGODAGAMAGE, A. U. WAIDYARATNE, D. A. W. DISSANAYAKA, AND A. G. N. M. SENARATHNE

Department of Electrical, Electronic and Telecommunication Engineering, Faculty of Engineering, Kotelawala Defence University, Colombo 10390, Sri Lanka

Corresponding author: Udaya Dampage (udayadampage@ieee.org)

ABSTRACT This research proposes a customer-interaction scheme that enhances customer-satisfaction through spatial-augmented-reality and deep-learning-based emotion-recognition for restaurant 4.0, by monitoring user-experience levels using facial expressions. The customer-satisfaction analytical-model provides environmental knowledge-based dynamic capabilities to the human-centered dining environment, which is also utilized as an input to logistics 4.0 supply chain management, business-processes, and decision-support-systems for future analytics. The perception of the quality of food was enhanced by the recreation of the live environment on the preparation of the menu ordered, utilizing the waiting time after each ordering session. The dishes are being portrayed in three-dimensional (3D) virtual menu also, adding SAR features in a special angle creating a 3D illusion to the naked eye. Menu suggestions are also proposed depending on the recommendations of the analytical model. The deep learning model monitors customer-satisfaction levels through emotion recognition. The performance was analyzed with numerous experimental evaluations with ambient light levels and desired viewing angles, where we found optimal angle values for spatial augmented reality applications. A survey was carried out to analyze user perception on evaluating the proposed system. The results revealed 87.5% of responders were very satisfied with the 3D virtual experience. 79.2% indicated rareness of feedback on food and service and more than 50% liked a system that will automatically measure their satisfaction. The results indicate enhanced customer-satisfaction levels compared to existing schemes. The resulting insights may lay a foundation for a novel approach towards the management of user-experience, business-processes, decision support systems, and supply chain management of restaurant 4.0.

INDEX TERMS Three-dimensional displays, customer satisfaction monitoring, deep-learning, emotion recognition, projector-based spatial augmented reality, restaurant 4.0, knowledge based dynamic capabilities, human centered design, logistic 4.0, targeted marketing.

I. INTRODUCTION

Customer satisfaction is a crucial factor that depends on the quality, productivity, and nature of services offered by a particular service provider. In the case of restaurants, customer satisfaction is a property of the restaurants' image, customer interests, dining environment, quality of food and the price to be paid. The dissatisfaction of customers leads to lower profits, which in turn leads to the downfall of a business, also affecting the business's reputation. Since the profitability of any business depends upon its sales, restaurants need to make sure to maintain customer satisfaction and be pleased enough with the services to keep returning. Customer retention ensures the continuity of any product or service. Therefore, service providers are interested in implementing strategies to enhance the quality of user experience to reduce customer turnover or churn rate. Restaurant 4.0 is not only automation, but it should mean the best experience for customers too. Present-day restaurants embrace novel technologies to attract more and more customers to facilitate a convenient experience. As per the authors' survey results, there is a requirement of decision support systems driven by customer expression and data, with predictive analytical capability, and extensions to marketing and logistics 4.0 operations with

The associate editor coordinating the review of this manuscript and approving it for publication was Mehul S. Raval.

the goal of enhancement of the overall quality of customer experience environmental knowledge-based dynamic capabilities. Furthermore, the authors felt that real-time analytics and developments of spatial augmented reality provide a golden opportunity to swiftly enhance a human-centered dining environment, which has not been exploited so far adequately. Hence the maintenance and enhancement of the above are paramount for survival in the competitive marketing environment.

This research work proposes a novel scheme that analyses user experience through a customer expression-based deep learning network and initiates a paradigm shift in the conventional dining experience through spatial augmented reality to make a huge impact on customer satisfaction in restaurants 4.0.

Furthermore, perception of the quality of food also enhanced by the recreation of the live environment on the preparation of the menu ordered; utilizing the waiting time after each ordering session. Initially, a virtual menu driven by a web page is projected onto the table using a Three-dimensional (3D) projection by which the customers can interactively choose dishes after examining how the dish looks in quality and quantity. The dishes are being portrayed in 3D also adding Spatial Augmented Reality (SAR) features in a special angle creating a 3D illusion to the naked eye. By using photogrammetry, we could portrait an identical 3D model of restaurant dishes. With the use of software's parallax effect was added to the video animation to bring out the 3D effect. A virtual restaurant background is created on the walls with relaxing videos and soothing soundtracks to enhance the restaurant ambience as the restaurant ambience deals more with the sensory and emotional aspects. On the analysis of the ordered menu and based on preferences available within the database, menu suggestions are also proposed depending on the recommendations of the customer satisfaction analysis model. This provides customers with a firsthand experience at the restaurant; known as ''Business to Customer'' (B2C) targeted marketing strategy. Post-processing results are utilized to determine the profit margin values and also to enter data into logistics 4.0 supply chain management, business processes, and decision-support systems to handle the replenishment of the supplies. Overall, the research outcome proposes a comprehensive scheme to monitor, analyze and enhance customer satisfaction with the marketing and logistic extensions, utilizing spatial augmented reality for smart restaurants.

One of the major challenges faced was to outstand spatial augmented reality features using a budget multimedia projector as the 3D illusion breaks when pixels are visible. Our project used different visual techniques to mitigate the challenge and create the illusion with expected quality and also conducted a test under standard ambient light intensity ranges in restaurants to analyze how colour and contrast get affected due to ambient light. Another challenge was to find out the distortion angles of the 3D illusion as it depends on the viewing angle of the customers. We conducted several tests and determined optimal angles for different viewing distances (Figure 1- parameter (i) and α).

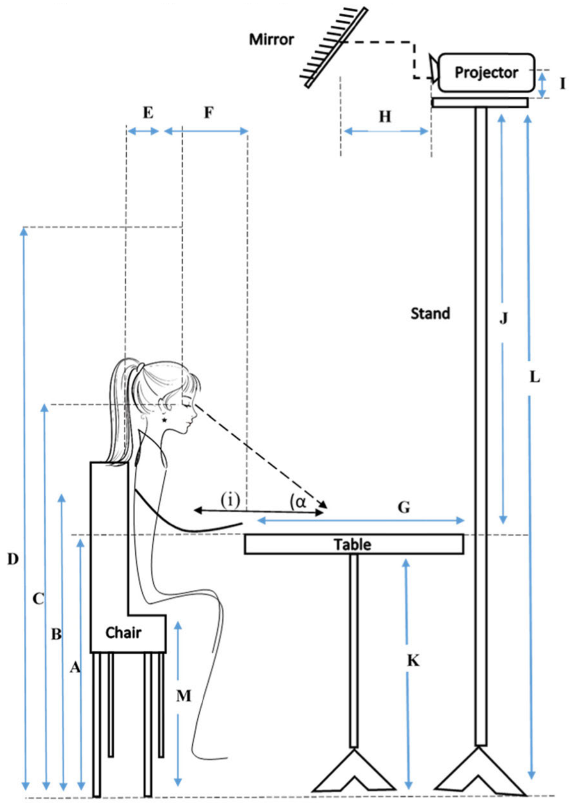

FIGURE 1. Project Hardware Setup: Designed considering restaurant related engineering ergonomics.

We had also conducted a user perception survey to perceive how likely customers are to embrace our project concept and it scored the highest satisfaction level on the Likert scale. We are certain that the outcomes of this project will set a precedence for future SAR projects as projector-based SAR is still an emerging research area in creating 3D illusions. Also, the analytical model provides environmental knowledge-based dynamic capabilities to enhance a human-centered dining environment.

II. RELATED WORK

A. CUSTOMER SATISFACTION IN RESTAURANTS

According to Poushneh and Vasques-Parraga's [1], augmented reality (AR) and virtual reality (VR) could provide higher user satisfaction, and could enhance user willingness to a product. According to Qodseya et al, the performance and reputation of restaurants dependent on customers' satisfaction as a metric [2]. Customer satisfaction measurement is a dynamic process, and restaurant comprehensive evaluation theory and methodology of user experience are required to be improved and perfected [3]. According to Qodseya et al main factors affecting customer satisfaction in restaurants are; the property of the restaurants' image, customer interests, dining environment, quality of food and the price to be paid. Authors [4] has pointed out that food quality is one of the prime factors impacting a particular restaurant's customer satisfaction, Andaleeb and Conway [5] argue that food quality is at the third-highest priority and emphasized service quality and restaurant ambience [4], [6] that make a significant impact on customers' satisfaction. AI can also assist restaurant operators in deciphering data to improve the dining experience for their customers [7].

Moolman and Hermanus [6] have concluded that food quality, service quality, restaurant ambience, the quality of facilities, and the presence of management as prime attributes for customers' overall dining satisfaction. Food quality and overall dining satisfaction were regarded as more important attributes for restaurant customers' decision to return to a mall restaurant. The authors further stated that the ambience connected with the sensory and emotional aspects like lighting, music, temperature privacy, and comfort, whilst the quality of the physical facilities connected to the tangible aspects of the facilities. The growth in the restaurant industry over the past years can be attributed mainly to a change in the modern way of life as consumers are nowadays experiencing an increasing scarcity of time, resulting to eat out rather than spending their scarce time cooking meals at home [6]. In today's highly competitive restaurant industry 4.0, many firms have been focusing on competitive strategies to improve service quality as it leads to enhance customer satisfaction, then enhances repeat patronage, finally resulting in increased profits and customer loyalty for the restaurants [8].

B. AR, VR AND PROJECTION-BASED SPATIAL AUGMENTED REALITY

The virtual environment of augmented and virtual reality provides a platform to interact with virtual objects and gives out an immersive human-centered design and user experience [9]. The type of augmentation could range from a textual display of data overlaid on real-world scenes or items to fully interactive 3D graphics scenes merged into real-world scenarios [10]. Swan and Gabbard [11] argued that the maximum prospect of AR meshed with viewing and interacting with the real world requires new philosophies to back up heads-up facts, presenting ways and interactions. They also state that user-based experimentation can help to accomplish a preferable understanding of underlining perceptual as well as ergonomic concerns related to augmented reality displays. Compared to SAR technology, in VR and AR users have to either wear HMD (Head Mounted Device) or use a handheld device like a smartphone to enter the virtual world [12]. This disadvantage can be eliminated using SAR since it uses the real environment objects and surfaces to give out an immersive experience for the user. With the advancement of 3D technology, spectators will be able to perceive 3D without the use of any special eyewear [13]. Projection-based augmented reality projects a light beam onto the desired surface with the use of single or multiple projectors to guide tasks in workspaces without consulting information or details from another place. With the use of stationary sensors or cameras, projection AR can track objects with or without fiducials [14]. To minimize the computational complexity of tracking algorithms, a workspace environment like lighting can be controlled [15]. The SAR technology mostly uses 3D visualization, which attempts to show by projecting 3D information onto a 2D plane. We have used 2D images to be displayed as 3D objects by manipulating the perspective angles and illusion by using depth of field and changing the colour contrast. It can be considered as an advantage for designing simple SAR systems like restaurant menus because rendering 2D images requires less computational power compared to 3D model rendering.

Bimber, & Raskar states that video projectors are becoming popular due to enhanced capabilities and reducing cost. Unless like desktop screens, one interesting advantage is being able to virtually project larger images than the actual display device. Novel and innovative information displays make use of this potential in the research stage to implement systems that go beyond simple screen presentations [16]. It is important to maintain consistent lighting between the real environment and the virtual for convincing AR applications. Bimber & Raskar furthermore states that "image processing, inverse rendering, inverse global illumination, image-based, and photorealistic rendering techniques" are used to map images and videos into the real world. Lack of real-time processing does not support devices that require interactive frame rates and limits the approaches to a combination of desktop screens and an unresponsive user interaction.

Belgian-based company Skullmapping, run by Antoon Verbeeck and Filip Sterckx, has demonstrated 'Le Petit Chef' proving that small-scale visual mappings in an impressive way, narrating a story of a small animated chef projected onto the dinner table and cooks their food on the plate [17], [18]. They have used Panasonic 4K projectors which are currently expensive. We used Epson EB-X41 [19] and implemented the system in a cost-effective method without breaking the 3D illusion and preserving SAR features. We upgraded the dinner show concept to provide a full package starting from a customizable virtual à la-carte menu, the entertaining video shows to utilize the waiting time, order, and pay from the virtual menu itself and includes temptation marketing features. According to Sterckx people think that the 3D effect in the movie is a hologram or a 3D projection. He states that it is a normal projection with a specific optical illusion that they use, by using a long distorted image from the right point of view [17], [20]. In our research, we have tested and optimized the distortion angles for different viewing angle distances which creates the 3D illusion on the eye. The 'AR lamp' projects interactive animated content of dishes in the menu indicating real portion size in 3D, with realistic and tasty details to boost the perception of the restaurant brand [21].

According to Apogaeis AR is being used in many business platforms, as it is one of the top upcoming game-changers creating a seamless customer experience that can bring rich, captivating virtual content to increase sales and add value to the customer experience [22]–[24]. It allows virtual objects to give a better sense of the look of the finished product than a flat image on a screen [22]. Onirix mentions extra dimension is added with the use of the AR menu to enjoy the meal. The added visualization gives customers an idea of how the dish looks, it's colours and it's textures perceiving deliciousness based on appearance [23], [25]. It was suggested to add information like ingredient lists and health tips into the AR menu. But in AR menus Customers either have to install an AR app or use the tablet device given by the restaurant to check out the menu. Depending on the hardware specifications (Graphical processing unit (GPU), Screen resolution, Battery level) of a customers' mobile device it limits the quality of the user experience. Also, visualizing the exact size and portion of the dish is difficult with smaller screen size. In our method mitigates these challenges as there is no need for additional handheld devices or app installations needed to see the 3D virtual menu and also helps maintain hygiene in a pandemic situation like covid-19, eliminating the use of restaurant provided tablet AR menu devices or traditional paper menus and no device damages due to falling or water/food spills. Also, an advantage of our proposed method (Using Projector-based SAR) is that it mitigates the blue light effect emitted from mobile or tablet screens. In our virtual SAR menu, we are giving the customers an insight of the quality and quantity of the dish projected onto a real environment with more information like ingredients and price. We have used the business-to-customer (B2C) marketing strategy to provide the first-hand experience to the customers through spatial augmented reality by suggesting relatable other delicious meals that the restaurant is offering and providing temptation information like seasonal offers through the virtual menu itself.

Users can engage with projected virtual information from any angle with immersive spatial augmented reality systems that leverage arbitrary projector positioning [26]. Koui, Emili in their research [24] states that restaurant businesses try to come up with methods to increase and maintain customers. In most of the restaurants, images of food do not represent the quality and quantity of the menu item. It results in disappointment in the customers which can cause loss to the business. They introduced an AR-based tablet interactive menu in a preferable language choice to provide a dietary filter option by portraying the food in 3D using the photogrammetry method. The intention of using AR was to give the consumer and insight of the portion size and ingredient placement. Since our research proposes a projector-based spatial augmented reality system, it provides an added advantage of not having to use any handheld device such as the tablet to provide augmented features of portion size and quality of the dishes on the menu. Poushneh and Vasques-Parraga [1] stated that, Augmented Reality gives customers and buyers higher user satisfaction when using it because it is more entertaining and enjoyable to interact with the virtual information of the product.

Ellis and Menges [27] examined that the presence of a visible (real) surface near a virtual object significantly influenced the user's perception of the depth of the virtual object (Depended on the user's age and ability to use accommodation). Another study [28], [29] showed how the inclusion of accurate, realistic shadows provides more user performance and virtual object presence with important depth cues. According to Schmidt, S. Spatial augmented reality has the potential to change the way humans perceive objects in a real environment. Depth information should be considered to perfectly blend 3D virtual and real features [30]. The study was applied to four different illusions; modifications of the color temperature, luminance, blur, and parallax. The paper concluded that the results suggest the assumption of the parallax condition affected the perceived depth the most, which in our experimental studies also experienced and put to use in creating 3D videos. S. Schmidt, G. Bruder, and F. Steinicke found that to make the object appear closer to the observer, the luminance contrast between an object and its surroundings shall be increased [10].

C. DEEP LEARNING-BASED CUSTOMER SATISFACTION MONITORING SYSTEMS

As per the research findings by Qodseya *et al.* [2], the gathering of customer's behavior data during their dining is important for conducting research analysis and developing smart applications in many fields. It is crucial to focus on common events to gather raw data. As an example, think about how it is competitive to sell products at a food festival. When the area of the markets has spread is less, there is more competition among restaurants and cafes. It shows that selecting a particular restaurant or a cafe depends on customer satisfaction which indicates automatically the service and product quality of business processes. Therefore, we need decision support systems to identify to which extent, the particular customer has satisfied or not [32]. Which is much more important to be used in improving knowledge-based dynamic capabilities and the factors which are lacking. Authors [33] propose a method of measuring customer satisfaction level by their facial expression which expresses their emotional states naturally. Also, they suggest using supervision cameras since it's now being used everywhere.

The combining of emotion detection with the food industry is a turning point which is a novel experience for customers. This will tempt customers and attract them more to the business. The subject of human emotion is complex and has many undiscovered stages. But with the rapid development of computer vision in facial expression detection will mitigate barriers that are complex in near future [34]–[36]. This allows marketers to consider human emotions as a new fact than conventional to brand their products effectively. Also, it will lead to creating new structures of strategies in marketing campaigns [37].

Human emotion detection through their expression is a subcategory of face detection. Now facial recognition is used as a security level in most mobile phones to bypass the main system. Therefore, collecting such data may lead someone to think it is breaching their privacy. We cannot ensure how the data collection will be used by the software which is used to detect human emotion later on. By considering these factors, we used ''Amazon Rekognition''. The Amazon Web Services (AWS) show in their policy that input videos and images only takes for analysis of human emotions and data will not be saved.

D. DEEP LEARNING-BASED FACIAL EXPRESSION RECOGNITION

Hardianti *et al.* [31] in their project used a Logitech web camera and got a 96.43% real-time accuracy using 'Adaboost algorithm' but the detection range was limited and was detected only in certain position and conditions. The research Talegaonkar, et al, obtained test accuracy of 60% using the FER2013 dataset and Haar cascade classifier for facial detection; Since our project is run on a low light background and is related to food consume it needs a high level of expression recognition accuracy hence machine learning algorithms, neural networks are a perfect fit to be used with CK+48 dataset which is found in researches with more than 90% of accuracy.

To extract manifold properties from high-dimensional data, a variety of manifold learning methods have been used [38], [39]. These manifold learning algorithms, on the other hand, are unable to obtain an explicit projection matrix that can map a new sample into a low-dimensional space. F. Luo, H. Huang *et al.* in their research [38] utilizes neighbor points and corresponding intra-class reconstruction points to improve the intra-class compactness and the interclass separability. As the volume of data is increased, the performance of deep learning algorithms improves. Since it identifies features that overlap and then combines them to facilitate rapid learning, the deep learning architecture is versatile enough to be adapted to new problems in the future. Because of its ability to learn deep abstract knowledge through a hierarchical network, deep learning has gotten a lot of attention from the remote sensing community in recent years. However, most methods for improving feature extraction performance in hyperspectral imagery (HSI) fail to investigate the local geometric structure relationship between samples [39]. The research [40] proposes a novel DL approach called deep manifold reconstruction neural network (DMRNet) to address this problem. The approach in the research [41] uses a qualified auto-encoder to extract deep features from a hyperspectral image (HSI), followed by the construction of an intrinsic graph and a penalty graph to discover the discriminant manifold structure of deep features. Finally, the deep features are mapped into a low-dimensional embedding space in which intra-class manifold samples are compressed and interclass manifold samples are isolated.

According to the survey done by S. Li and W. Deng; shows a need for large samples of data in Facial Expression Recognition (FER) to train and get a higher amount of accuracy. The authors state that even though we have a large data set, it's poor in diversity. Facial expressions have large diversity which goes under many factors like gender, age levels, and ethnicity. Therefore, the authors suggest using deep learning techniques like ''Multitask deep networks and transfer learning'' [42]. The authors [43] suggest a novel method for automating the process of detecting damage to visually dominant regions of statues' faces, such as the eyes, nose, and lips, to in-paint them. The eyes, nose, and lips are first identified using a bilateral symmetry-based system. In the research ''Description Based Person Identification: Use of Clothes Color and Type'' [44], A motion segmentation based on frame differencing is applied to detect a person. Morphological closing is applied to reduce noise and blob detection separates the region. The research done by B. Hasani, M.H. Mahoor proposes a 3D Convolutional Neural Network (CNN) method for FER in videos of which the new network architecture consists of 3D Inception-ResNet layers. Together it extracts the spatial relations within facial images and also the temporal relations between different frames in the video. Facial landmark points were also used as inputs to the network which emphasize the importance of facial components rather than regions that may not contribute significantly to generating facial expressions. In our project, we use AWS, which uses deep learning technologies to analyze images. It continuously increases support for facial analysis, with the added advantage of having millions of images in their databases, which makes it more accurate than a locally trained model because more computational power is required to process larger data sets.

As per the authors' survey results, there is a requirement for a platform driven by customer expression and data. Therefore, our project proposed a customer satisfaction monitoring scheme combined with predictive analytical capability and extensions to marketing and logistic operations with the goal of enhancement of the overall quality of customer experience.

E. ERGONOMICS, STANDARDS AND USE OF ANTHROPOMETRIC DATABASE

The application of ergonomic principles provides a standardized approach for the evaluation of interaction (between human, machine, and environment). The use of a country-specific anthropometric database helps ergonomically fit the population of specific countries with product designs. Bach and Scapin [45] have studied issues with the ergonomic evaluation of Mixed Reality (MR) systems. Their findings indicate the lack of usability evaluation methods specific to MR systems. They discuss the adaptation of similar evaluation methods used in other domains to evaluate MR systems. The study identified three suitable categories:

(1) Questionnaires and interviews
(2) Inspection methods
(3) User testing

To acquire subjective data, user preferences, missing functionalities, and compare performance statistics; questionnaires and interviews can be used [45]. Because there is currently a lack of understanding regarding specific ergonomic concerns and design standards for mixed reality systems, inspection techniques might be limited. Informal user research, formal experiments, task-based usability studies, heuristic evaluations, and the use of predictive performance models are all examples of traditional VE usability evaluations [46]. Due to a lack of established and proven rules and models, non-user-based evaluation approaches such as employing heuristics or prediction models are problematic. 11 surveys were offered in the evaluated papers [46], with the majority of responses using a 7-point or 5-point Likert scale. The favorite technique, or how agreeable each technique is, is the most widely used metric. Other often asked topics concern ease of use, difficulty, perceived accuracy, and perceived speed.

'Proper vision requires appropriate luminance of an object, that is, the energy reflected or emitted from it, which meets the eye'. Depending on their age, experience, attitude, and preconceived ideas People differ greatly in their interpretation of visual data. People also differ in their abilities to recognize colours and focus clearly on visual targets, and usually significant changes in these abilities occur as one ages. Nevertheless, there is a common similarity in how the human visual sense functions, which allows us to develop ergonomic recommendations [47]. The fully functioning human eye senses and can adapt to increases and decreases in the illumination of the retina over a wavelength range of about 380–720 nm (violet to red). We can see objects if they are bright enough (either by generating light or by reflecting it) to carry sufficient visible energy onto the retina. On the retina, the minimal intensity required to trigger the sense of light perception is 10 photons. It causes an illuminance of about 0.01 lux. At such low intensity, the main perception is of dim light, not of color, because only rods are activated. When the illuminance of the retina exceeds about 0.1 lux, both rods and cones respond, and the cones report colors'' [47].

According to ''National Optical Astronomy Observatory: Quality Lighting Teaching Kit'' [48], recommended lighting level for dining areas is 150 - 200 lux. Restaurant lighting is an important part of the architectural and interior design of cafe and restaurants because the ambience of the cafe and restaurant is overriding as food and service forming a good first impression in customers. There are international standards specifying requirements for electronic displays. In the standards of EN ISO 9241-300 subseries [49], ergonomics aspects of the 'human–system interaction' are treated concerning the prerequisite of electronic visual displays establishing the requisites that displays require to guarantee adequate visual ergonomic performance to be met during normal use. Blue light is known to be a cause of digital eye strain. Symptoms may range from mild to severe (including focusing difficulties, dry eyes, blurred vision, eye irritations, and headaches). Additionally, long-term exposure to blue light may cause permanent eye damage and contribute to the destruction of the retina and macular degeneration. Even though projectors also produce blue light, it does not reach the eye directly (since the viewer is not staring straight at the light source). Prior to reaching the eye, the light bounces off another surface (a projector screen or wall). This reduces the amount of blue light that reaches the eye since the surface would absorb a portion of damaging wavelengths. In summary, direct light sources are harsher on the eyes in comparison to indirect light [50].

III. PROPOSED METHOD

The methodology creates a novel scheme that analyses user experience through a customer expression-based deep learning network and customizes the dining environment to enhance customer satisfaction in smart restaurants (Figure 5). The perception of the quality of food was also enhanced by the recreation of the live environment on the preparation of the menu ordered utilizing the waiting time after each ordering session. Initially, a virtual menu is projected onto the table using 3D projection by which the customers can interactively choose dishes after examining how the dish looks in quality and quantity. The aforesaid menu is driven by a web page designed using Wix.com. The virtual menu contains features such as food suggestions, seasonal offers, and best-selling dishes as marketing strategies to enhance user willingness to purchase food and beverages. The dishes are being portrayed in 3D also adding SAR features in a special angle creating a 3D illusion to the naked eye. Photogrammetry can be used to portrait an identical 3D model of restaurant dishes. With the use of video editing software, the parallax effect can be added to the video animation to bring out the 3D effect. The spatial augmented reality video shows will be added to keep the customers entertained during the waiting time on placing the order until the dish arrives. A virtual background is created on the restaurant walls with relaxing videos and soothing soundtracks to enhance the restaurant ambience as it deals more with the sensory and emotional aspects in providing a human-centered dining environment.

On the analysis of the ordered menu and based on preferences available within the database, menu suggestions are also proposed depending on the recommendations of the customer satisfaction analytical model. The deep learning-based facial expression recognition system is running in the background to monitor customer satisfaction levels through facial expressions. The captured data will be processed and loaded into the just-in-time logistic management model; where, the post-processing results will be utilized as an input to logistics 4.0 supply chain management, business processes, and decision-support-systems used for future analytics such as determination of the profit margin values and also handle the replenishment of the supplies. Outcome of the research proposes a comprehensive scheme to monitor, analyze and enhance customer satisfaction with the marketing and logistic extensions, utilizing spatial augmented reality for smart restaurants. The following subparagraphs will explain each subsystem in detail. The experimental setup of the research is depicted in Figure 1, with the relevant parameters of the setup as listed in Table 1.

A. COMBINING PROJECT SETUP WITH RESTAURANT-RELATED ENGINEERING ERGONOMICS

Utilizing the information gathers during the literature survey, we analyzed the minimum specifications needed to satisfy

TABLE 1. Selected measurements for project hardware.

	Description	Selected Measurement (cm)
A	Height horizontally equal to table height	74
B	Average height of a Child (5 years old)	94
C	Average height of Male(C_m), Female(C_w) when sitting	C_m - 120 C_w - 110
D	Average height of Male(D_m), Female(D_w) when standing	D_m - 155 D_w - 145
E	Distance from chair backrest to eye	5-15
F	Horizontal distance from eye to table	17
G	Dining table width	28
H	Horizontal distance between the center of the mirror to the projector lens	30
I	Vertical distance between the center of projector lens to projector base	5
J	Vertical distance between tabletop to projector base	
K	Table height	74
L	Height of the stand till projector base	
M	Height of the chair	40
(i)	Viewing distance	
α	Viewing angle	

the requirements for SAR projection under standard ambient light levels of a restaurant (0 to 200 lux). The main factors taken into consideration when selecting the projector were; color light output (brightness) [51], contrast ratio, resolution, and throw ratio. In SAR table projection, the distance between the viewer and the table is smaller compared to traditional projection mapping. Therefore, the displaying elements should be smaller to match with the viewer's perspective and it is necessary [52] to be displayed in high resolution to avoid blurry, pixelated images and to enhance details of projecting images to form a 3D illusion to the naked eye.

A comparison of specifications of commonly used projectors was carried out to identify the most suitable model which offers the requirements for SAR at a reasonable cost, without compromising the requirements needed to create 3D illusions. The project hardware setup was designed according to standards of restaurant ergonomics [49], [53] and to fit with Asian anthropometric data [54], [55], [56] by considering the height of eye level when an average person is sitting and standing (values at levels B, C, D described as in table 1. As depicted in Figure 1, we selected standard restaurant table dimensions as our SAR plane. All the parameters were determined considering the possible positions of the table, chair, and customer viewing angle when designing SAR projection to render 3D objects in the correct angle and size. Table 1 shows the selected measurements for project hardware setup design. The eye-level when an average person is sitting and standing obtained through anthropometric database were used when optimizing the distortion angles of the SAR content to make the 3D illusion at the correct viewpoint of the eye. The next step was to determine the proper height to fix the main projector, which projects the user interface of the menu of the restaurant within the constraints of the table dimension. Several tests were conducted to find out the suitable height to fix the projector without disturbing the user's perspective. The projector-throw distance calculators provided by the manufacturers were used to calculate the suitable height to place the projector to obtain the projection onto the table. For experimental purposes, we have designed an adjustable projector stand as an alternative to be used with any projector at any height to project onto a selected surface, rather than ceiling/mounting of the projector setup.

B. DESIGNING OF VIRTUAL MENU AND SAR ANIMATIONS

The design of the restaurant menu was carried out using a cloud-based platform to create an HTML5 website (Figure 2 and Figure 3). During the designing process, we followed the visual design principles, such as scale, visual hierarchy, balance, and contrast, to enhance the User Experience (UX) of the User Interface (UI).

When designing the restaurant menu we mainly used 3D viewer software to view and test the 3D models' properties and windows 3d paint to modify and design 3D models to embed SAR features. The Blender open-source software was also used to correct the viewing angles, texturing, and animate 3d models. The software's Wondershare Filmora and Adobe after effects were used to design and create videos of the 3D rendered models.

An aerial perspective can be observed for an objects' texture and shading as well as the contrast between the object and its background. Therefore, by manipulating the luminance values of adjacent regions, the characteristics of aerial perspective were simulated and an illusion of depth was added

FIGURE 2. Designed restaurant menu with SAR features.

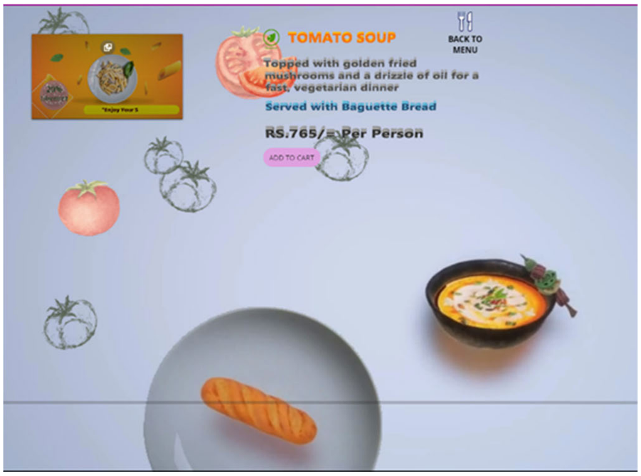

FIGURE 3. Designed restaurant menu animations manipulated with SAR features.

to the 3D images. We have also used static images to feature up the parallax effect of the moving 3D dishes which we had designed. The texts, images, and animations in the menu were created using a special angle which creates an illusion and 3D effect, as presented in Fig. 3, at the right viewpoint on the eye at height values of B, C, D as per figure 1.

Different colour combinations, text/image scaling, spacing, and illustrations were considered when designing to provide a better visual hierarchy for the user to deliver a rich and novel experience in using the digital menu. Also, we have been concerned to design a simple but well-equipped method of food selecting and ordering menu so that it could be customized according to the restaurant's requirements.

C. DEEP LEARNING-BASED CUSTOMER SATISFACTION MONITORING SYSTEM

The webpage containing the restaurant menu with the function buttons is hosted on the local network. When a button is clicked, the button type is sent to the flask server as a POST request. The endpoint is a flask server that receives the data and analyzes it.

After analyzing, the python program plays the food video according to the received data. Then it starts taking photos with intervals of 1.5 seconds. Each captured photo is sent to the Amazon Rekognition service and receives back a json file containing analyzed data with their respective confidence values. After decoding those data, the emotion type with the highest confidence level is saved into a temporary array. This process continues another 9 times. Then the most repeated value from the array is chosen.

On completion of the above process, all the captured photos and the array of data are deleted. The remaining most repeated emotion type is pushed into the MySQL database table according to the order and the button (function). The MySQL database contains 3 tables with emotion data. These tables contain 10 columns which contain food type and the remaining columns for 9 emotions types taken from the python program. The three tables are emotions for projected food videos, emotions for waiting time videos, emotions when taking the foods. These data are then accessed using Metabase software which is hosted in an eclipse jetty server. The Metabase software is used to represent the database data in an intelligent and user-friendly way (Figure 4).

The percentage level of the most repeated emotion type under each order is then extracted using a python-based program to represent the satisfaction level of the order. Each order indicates a percentage of customer satisfaction on the dishes included in the order as depicted in figure 4. Implementation of the supply chain management logistics management model with a user-friendly interface for easy use of restaurant management will be developed further as the second stage of this project under future research. Hence the restaurant management will be able to visualize which dishes customers mostly enjoy and adjust prices accordingly. The real-time gathered database on customer satisfaction can be used to analyze customer interests under different seasons of the year, age, gender and experiment on changing the menu accordingly. Therefore, the system provides a base for upgrading profit margins and also handle the replenishment of the supplies

All servers are hosted in different devices for load balancing; the Python program is hosted in a flask server, MySQL DBMS is hosted on an apache server, Metabase is hosted on an Eclipse jetty server, the web app is hosted on an angular web pack dev server. All servers are in one local network and all the servers' connections are encrypted. Non-storage API operations were used, hence no data can be traced back to customers. No media is saved in the local storage or the Amazon Web Service (AWS) Rekognition service. So the personal information that facial recognition software collects to analyze ensures the privacy of customers.

IV. PERFORMANCE ANALYSIS AND RESULTS

The effect of ambient light intensity on the projection surface (On the table) and on the user's eye was tested with an intention to provide a detailed analysis on multimedia projector

FIGURE 4. Representation of customer satisfaction on ordered dishes.

control parameters as it has a direct impact on the quality of spatial augmented reality features.

We have tested and analyzed how the ambient level affects colours and contrast of the projection surface to identify which scenarios can break the 3D illusion of SAR. So that it provides an insight of how to choose and optimize parameters of the projector under any ambient level of restaurants. Providing a performance analysis on the above was considered as a helping factor for future SAR projects as projector-based SAR is an area that is still under research to enhance 3D illusions. Furthermore, a survey on user perception was conducted on the proposed method to analyze system performance if the system is implemented in a restaurant and to determine how likely customers would embrace it.

A. TESTING EFFECT OF AMBIENT LIGHT INTENSITY ON THE PROJECTION SURFACE

Testing was done (Figure 6) inside a 15ft × 15ft square room providing constant lighting using brightness controllable ceiling mounted light. An Extended Graphics Array (XGA) projector Epson EB-X41 with a resolution of 1024 × 768 and with a color light output of 3,600 Lumen was used for testing. Testing involved ambient light intensity levels 0lux, 50lux, 100lux, 150lux, 200lux because the best luminance from projected screens can be achieved under low light conditions and the recommended lighting level for dining areas [53] are 150lux to 200lux. The test was performed for RGB colors, red, green, blue, and including magenta, yellow, and cyan with six contrast testing patterns proposed in EN ISO 9241-306 (Figure 8) for measurements of luminance under each ambient light intensity level. The test color patterns are shown in Fig. 4 and 5. The test values; illuminance light intensity on the table and luminance light intensity on the eye at different heights were measured using the UT383 mini light meter.

The heights when a person is sitting and standing were calculated with an average taken from a sample of people and also concerning the research findings of [14], [54]–[56].

- Men
  - o Cm - Sitting – 120cm
  - o Dm - Standing – 155cm
- Women
  - o Cw - Sitting – 110cm
  - o Dw Standing – 145cm
- Child (5 years old) sitting – B – 94cm

Dimensions of table and chair were taken according to standard requirements of restaurant ergonomics.

- Table Dimensions (2 people)
  - o Width × Length × Height – 94cm × 71cm × 74cm
- Height to Chair seat – 40cm

When tested the effect of ambient light intensity on the projection, the values were measured on the table and at eye level. This was recorded for nine different Contrast- Brightness (C-B) Combinations (a-i) at each test scenario. (Table 2).

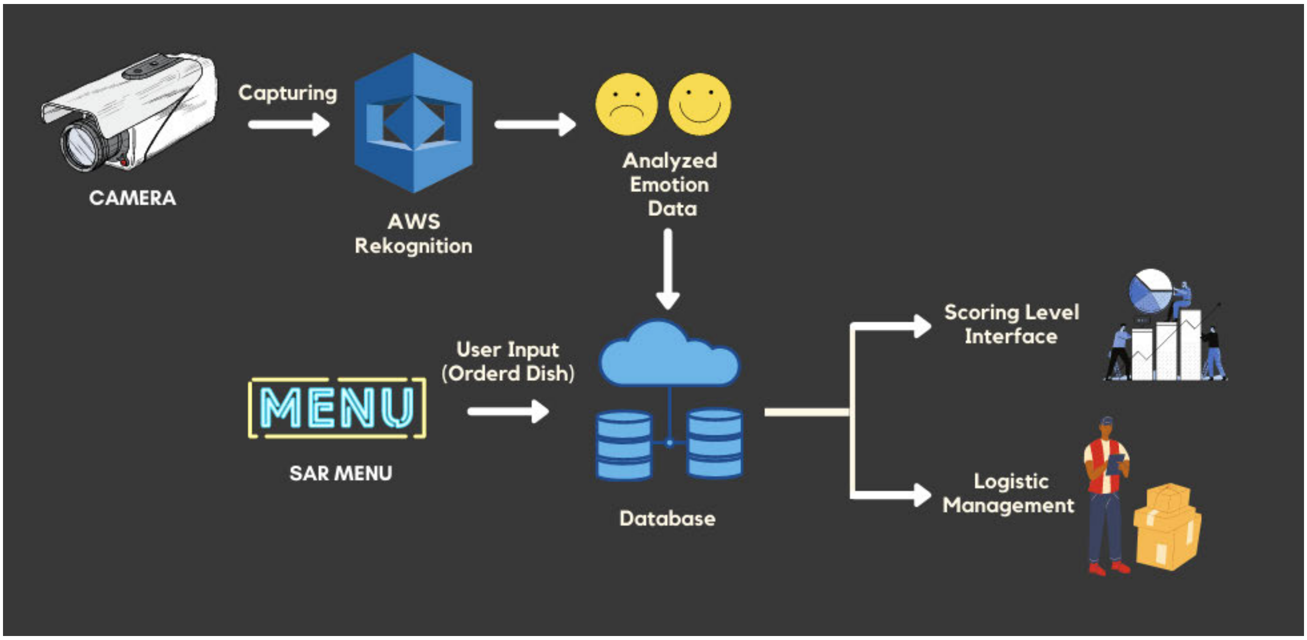

FIGURE 5. Figurative representation of the functionality of the restaurant scoring system.

FIGURE 6. Experimental setup for testing effect of ambient light intensity on the projection surface.

B. TEST RESULTS ANALYSIS

Testing was conducted in a 15ft × 15ft square room with low natural ambient light. Projecting test images onto a 74cm × 94cm tabletop. Effect of ambient light on RGB colors as per figure 7, and six contrast patterns proposed in EN ISO 9241-306, for measurements of luminance as per Fig. 8, under each ambient light level were tested for several contrast-brightness combinations of projector under different ambient light intensity levels of 0, 50, 100, 150, 200lux, by adjusting the light intensity using a ceiling-mounted Light Emitting Diode (LED) lamp of which the brightness intensity can be controlled using a remote controller. UT383 mini light meter was used to measure lux values. During luminance testing on the eye; measurements were taken at six different height levels A, B, C_M, C_W, D_M, D_W of Fig 1. Throughout the testing process of each level, certain conditions like the position of the table, chair, and test setup were kept constant.

In this research chi-square test method was used to statistically evaluate the change in luminance and illuminance at each scenario. Table 3 in the Appendix presents the statistical

TABLE 2. Contrast-Brightness combinations used for testing (a-i).

Combination	a	b	c	d	e	f	g	h	i
Contrast	0	0	0	50	50	50	100	100	100
Brightness	0	50	100	0	50	100	0	50	100

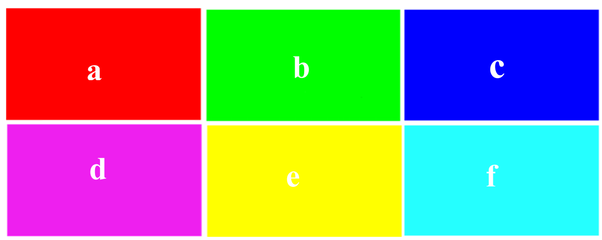

FIGURE 7. RGB colours used for testing (a) #FF0000 (b) #00FF00 (c) #0000FF (d) FF00FF (e) FFFF00 (f) 00FFFF.

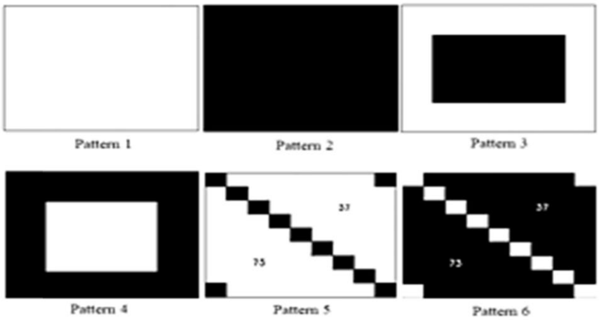

FIGURE 8. Contrast testing patterns (based on the proposed pattern in EN ISO 9241-306).

results obtained. Chi-square values are favorable in terms of testing objectives; in testing the effect on projector screen luminance due to different ambient light and different height levels of the eye. Statistical results show that the illuminance of RGB colors and contrast test patterns on the table are highly dependent on the ambient light conditions. It proves that ambient light intensity affects the quality of luminance of the projection surface, which is why it needs to be considered because high-quality image luminance and preserved contrast levels are necessary to conserve the 3D illusion of SAR. Even though the observed values had a slight change due to the non-uniformity of ambient light when measured across the table at different positions for the same test image, the chi-square statistical values of ambient light effect at a different position on the table show that those two parameters have independent characteristics since the variation of lux values were smaller in comparison. The results also show that the luminance of RGB colors and contrast test patterns on the eye and luminance at each height level on the eye are also dependent on ambient light conditions. The accuracy of the calculation is high because of the number of test samples in the controlled experiment.

Consideration of the correct C-B combination is very much important when projecting SAR because the color illuminance directly affects the 3D illusion formed on the eye. The colors White and Cyan have the highest luminance where else Red has the lowest. Cw, Cm, Dw, Dm height positions have high luminance on the eye due to ambient light and projection luminance. C-B combinations 'i','f','c' have the highest lux value measured during the test in which the projector brightness was 100%, it was observed that the colors fade when brightness increase. C-B combinations 'a' have the lowest (C-0, B-0) lux value measured and there the colors appeared darker. It should be noted that for the symbols on the screen to be visible, there must be sufficient contrast concerning the background; symbols and background must therefore have a different value of luminance. It was clear in the test results (Figure 9) that 0% and 100% brightness degrades the colours of the image and breaks the 3D illusion. It was observed the brightness value around 50% with higher contrast satisfy the colour quality to preserves the 3D effect.

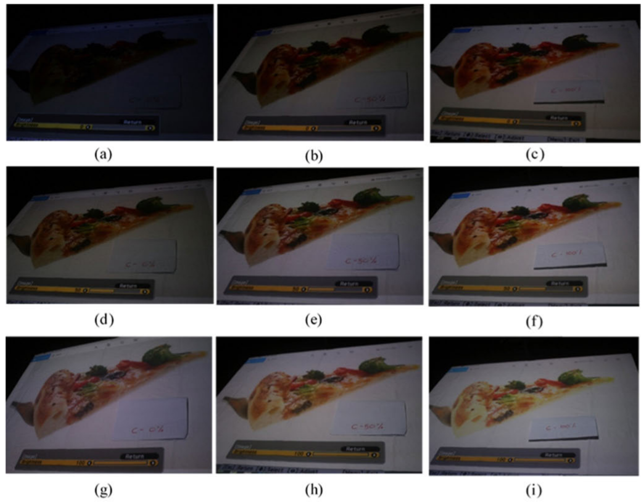

FIGURE 9. Colour degradation under different C-B combination; Figures shows C-B Combinations (a) C-0,B-0 (b) C-50,B-0 (c) C-100,B-0 (d) C-0,B-50 (e) C-50,B-50 (f) C-100,B-50 (g) C-0,B-100 (h) C-50,B-100 (i) C-100,B-100.

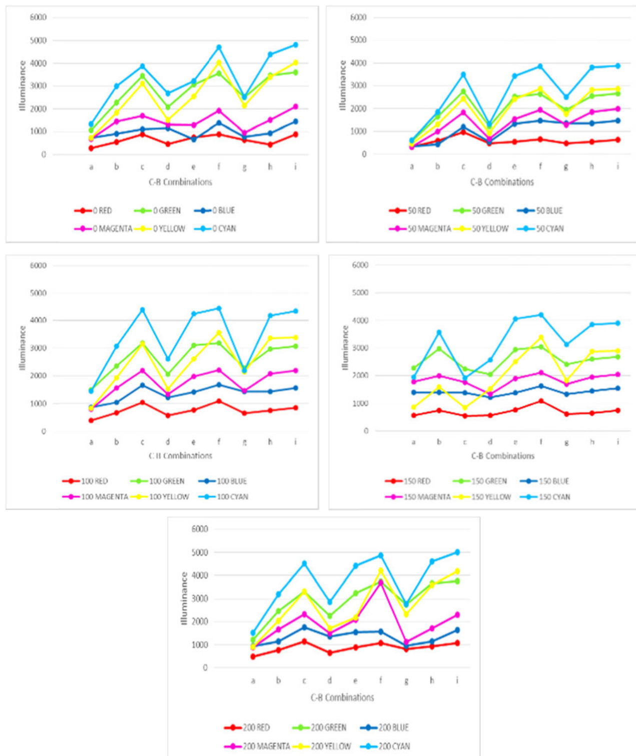

FIGURE 10. Representation of test results for RGB colour luminance testing under each ambient light level (a) 0lux, (b) 50lux, (c) 100lux, (d) 150lux, (e) 200lux, for the nine C-B combinations.

Fig. 10 shows the graphical representation of the test results. According to test results, the highest colour luminance was received at an ambient light intensity of 0 lux. Our projection setup using an XGA projector showed sufficient colour luminance at ambient light levels 150-200lux; which are the standard ambient light intensity levels in restaurants. To get the highest colour luminance at the position of eye level of an average human sitting (Cw, Cm) was one of the objectives of the experimental test, and the test results came in favor of the testing objective. The highest colour luminance was observed at Cm, Cw, Dm, Dw which is an advantage when creating the SAR illusion on the customer's eye when sitting.

C. ANALYSIS OF SURVEY DONE ON USER PERCEPTION

A user perception survey was conducted on our smart restaurant concept by inviting people to experience it. From a sample of 24 people, we asked 22 questions under 3 categories. From questions 1 to 6 we expected the customer's perspective about our setup and suggestion for improvements. Questions 7 to 12 gathers Demographic information of customers and from 13 to 22 questions were designed to gather data regarding experiences on previously visited restaurants.

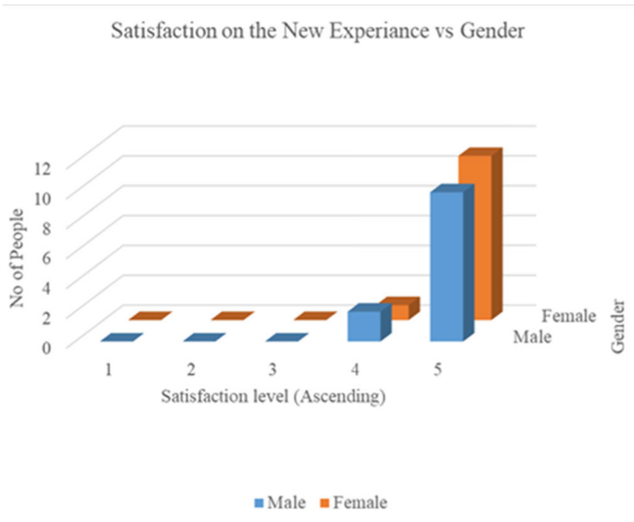

FIGURE 11. User ratings about satisfaction on the project concept.

87.5% were very satisfied with the new concept and would definitely come back to dine in the new virtual environment. 8.3% would probably come back and 4.2% was unsure that they would come back to dine with the new experience they had. None of the responders was dissatisfied with the new experience they had (Figure 11). The responders mostly like the concepts of providing a safe environment in a situation like covid19 with less contact between customer and staff, knowing the total bill from the virtual menu itself, being able to see the portion and size, being able to know the ingredients and interactive menu with 3D effects; which we provided them through our project.

The majority of people visit five-star restaurants for weddings (87.5%) and get-together parties (53.2%). 41.7% visits five-star restaurants for family gatherings, 37.5% for birthday celebrations and 29.2% for business meetings/conferences. Majority of 58.3% indicated 5-10 minutes as the waiting time till the ordered dish arrive. 12.5% replied 10-15 minutes and 16.7% as 15-20 minutes. 8.3% of people responds that they have received their meal in less than 5 minutes.

83.3% of the responses chats with friends during the waiting time, 70.8% of responder's check out the restaurant environment, 50% rechecks the menu, and 66.7% surf in social media. 75% of responders are very satisfied with the project concept to keep them entertained meanwhile wait for the dish to arrive and the other 25% were moderately satisfied with the entertaining video concept. None of the responses was dissatisfied with the concept of the project.

Most of the responses 79.2% indicated that restaurants rarely ask for feedback on Food and service. According to the responders, the majority of restaurants get feedbacks verbally (50%) and through forms (45.8%). 29.2% acknowledge the feedback method as email/online surveys. Most of the responders (58.3%) are willing to give feedback after they finish their meal.

Nine out of the total responders would tell the Restaurant Manager/Staff of their dissatisfaction if they were not satisfied with the service. 16 out of 24 are less likely to express their dissatisfaction. 45.8% of the responders would definitely like a system that will automatically measure their satisfaction rather than to personally give feedback. 29.2 % probably like the idea, where else 12.5% are unsure of it. 8.3% of the responders don't like to be a part of an automated customer satisfaction monitoring system.

V. CONCLUSION

In the case of restaurants, customer satisfaction is a property of it's image, customer interests, dining environment, quality of food and the price to be paid. Customer dissatisfaction leads to lower profits, which in turn, leads to the downfall of a business, also affecting the business reputation. Therefore, service providers are interested in implementing strategies to enhance the quality of customer experience to reduce customer turnover or churn rate. In this research work, we proposed a novel scheme that analyses customer interests through a customer expression-based deep learning network and makes an impact on customer satisfaction in smart restaurants through spatial augmented reality. 87.5% responded that they were very satisfied with the new concept and would definitely come back to dine with the new virtual experience. 79.2% indicated that restaurants rarely ask for feedback on Food and service. 45.8% definitely like a system to automatically measure their satisfaction rather than to personally give feedback. Therefore, the qualitative results of the survey show that the proposed SAR virtual menu concept has a high level of user satisfaction and customers are most likely willing to see it deployed in restaurants (Figure 12) and prefers an automated satisfaction monitoring system rather than to personally give feedback.

Perception of the quality of food is also enhanced by the recreation of the live environment on the preparation of the menu ordered, utilizing the waiting time after each ordering session. Majority of 58.3% indicated 5-10 minutes of waiting time till the order arrives. 75% of responders are very satisfied with the project concept to keep them entertained in the waiting time and the other 25% were moderately

TABLE 3. Statistical analysis of test results using chi-square test.

Ambient & RGB @Table DOF- 20		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	55.9	127.24	444.64	37.66	260.69	154.95	410.59	244	79.91
	P Value	3E-05	0	0	0.009	0	0	0	0	4E-09
	Significance level	***	***	***	**	***	***	***	***	***
Ambient & Contrast patterns @Table DOF - 20		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	195.63	192.13	27.1	191.42	126.35	47.93	213.89	234.75	100.9
	P Value	0	0	0.132	0	0	0.0004	0	0	8E-13
	Significance level	***	***		***	***	***	***	***	***
Ambient & Position @Table DOF - 64		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	13.92	12.06	6.41	3.73	75	78	11.91	12.44	6.7
	P Value	0.9	0.9	1	1	0.15	0.11	0.99	0.99	1
	Significance level									
Ambient & RGB @EYE DOF - 20		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	54.99	54.53	41.84	37.82	56.96	42.05	76.24	75.68	35.56
	P Value	4E-05	4E-03	0.002	0.009	2E-05	2E-03	1E-08	2E-08	1E-02
	Significance level	***	***	**	**	***	***	***	***	***
Ambient & Height @RGB on EYE DOF - 20		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	31.22	42.72	42.32	37.14	23.12	20.6	27.16	37.35	37.05
	P Value	0.05	0.002	0.0025	0.01	0.282	0.42	0.13	0.01	0.012
	Significance level	*	**	**	**				**	*
Ambient & Contrast patterns @EYE DOF - 20		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	68.05	87.39	24.27	80.99	64.25	33.03	78.33	113.04	47.09
	P Value	3E-07	2E-10	0.23	2E-09	1E-06	3E-02	7E-09	5E-15	5E-04
	Significance level	***	***		***	***	***	***	***	***
Ambient & Height @Contrast on EYE DOF - 64		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
	Chi Square	27.37	38.53	37.68	31.95	29.61	33.16	22.07	39.32	39.86
	P Value	0.12	0.007	0.009	0.04	0.07	0.03	0.33	0.006	0.005
	Significance level		**	**	*		*		**	**

*p<0.05 **p<0.01 ***p<0.001 DOF – Degree of freedom

satisfied. Post-processing results of the analytical-model provides environmental knowledge-based dynamic capabilities to the human-centered dining environment, which is also utilized as an input to logistics 4.0 replenishment and business-processes. Overall, the research outcome proposed a comprehensive scheme to monitor, analyze and enhance customer satisfaction with the marketing and logistic extensions, utilizing spatial augmented reality for smart restaurants. This study can be a pioneering work that shows the usefulness of emerging technologies in practical application scenarios.

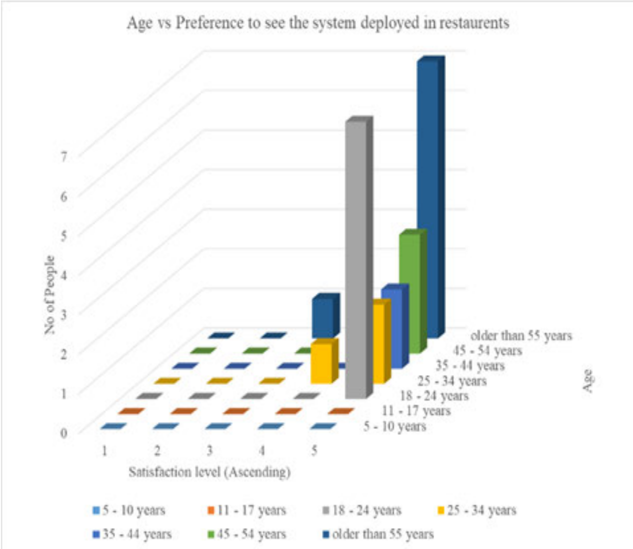

FIGURE 12. User ratings about satisfaction levels to see project deployed in restaurants.

FUTURE WORK

Further research on interactive display with Kinect depth-sensing cameras is in progress to develop a touch and gesture-based interaction system. Improvements in the scoring system based on facial expression and logistics management model are being carried out to implement a user-friendly interface for easy use of business processes. For a better estimate of emotions, it is important to take into account other contextual cues, such as the task the person is doing, the environment they are in, what they are saying, and their body's physiological cues.

APPENDIX

See Table 3.

REFERENCES

[1] A. Poushneh and A. Z. Vasquez-Parraga, "Discernible impact of augmented reality on retail customer's experience, satisfaction and willingness to buy," *J. Retailing Consum. Services*, vol. 34, pp. 229–234, Jan. 2017.

[2] M. Qodseya, M. Washha, and F. Sedes, "DiEvent: Towards an automated framework for analyzing dining events," in *Proc. IEEE 34th Int. Conf. Data Eng. Workshops (ICDEW)*, Paris, France, Apr. 2018, pp. 163–168.

[3] M. Sun, J. Gui, Y. Liu, and X. Zhao, "Analysis on food customer satisfaction—Survey on the Beijing customers of high-grade restaurants," in *Proc. Int. Conf. Manage. Service Sci.*, Wuhan, China, Aug. 2010, pp. 1–4, doi: 10.1109/ICMSS.2010.5577198.

[4] H. J. Moolman, O. Mhlanga, and Z. Hattingh, "The effect of restaurant attributes on customers' expectations and experiences in formal full service restaurants in Port Elizabeth, South Africa," *Afr. J. Hospitality, Tourism Leisure*, vol. 3, pp. 1–13, Jan. 2014.

[5] S. S. Andaleeb and C. Conway, "Customer satisfaction in the restaurant industry: An examination of the transaction-specific model," *J. Services Marketing.*, vol. 20, no. 1, pp. 3–11, 2006, doi: 10.1108/08876040610646536.

[6] H. J. Moolman, "Restaurant customer satisfaction and return patronage in a Bloemfontein shopping mall," *Acta Commercii*, vol. 11, pp. 129–146, Jan. 2011. [Online]. Available: https://www.researchgate.net/publication/307843700_Restaurant_customer_satisfaction_and_return_patronage_in_a_Bloemfontein_shopping_mall, doi: 10.4102/ac.v11i1.157.

[7] K. Eriksen. (2019). *Benefits of Artificial Intelligence in the Restaurant Industry*. [Online]. Available: https://www.deputy.com /blog/benefits-of-artificial-intelligence-in-the-restaurant-industry

[8] N. T. Kuo, K. C. Chang, Y. S. Cheng, and C. H. Lai, "The impact of service quality, customer satisfaction and loyalty in the restaurant industry: Moderating effect of perceived value," in *Proc. IEEE Int. Conf. Qual. Rel.*, Bangkok, Thailand, Sep. 2011, pp. 551–555, doi: 10.1109/ICQR.2011.6031600.

[9] A. Samini and K. L. Palmerius, "Popular performance metrics for evaluation of interaction in virtual and augmented reality," in *Proc. Int. Conf. Cyberworlds (CW)*, Chester, U.K., Sep. 2017, pp. 206–209, doi: 10.1109/CW.2017.25.

[10] S. Schmidt, G. Bruder, and F. Steinicke, "Depth perception and manipulation in projection-based spatial augmented reality," *PRESENCE, Virtual Augmented Reality*, vol. 27, no. 2, pp. 242–256, Feb. 2020, doi: 10.1162/pres_a_00329.

[11] J. E. Swan and J. L. Gabbard, "Survey of user-based experimentation in augmented reality," in *Proc. 1st Int. Conf. Virtual Reality*, 2005, pp. 1–9.

[12] M. Jamali, F. Golaghazadeh, S. Coulombe, A. Vakili, and C. Vazquez, "Comparison of 3D 360-degree video compression performance using different projections," in *Proc. IEEE Can. Conf. Electr. Comput. Eng. (CCECE)*, Edmonton, AB, Canada, May 2019, pp. 1–6, doi: 10.1109/CCECE.2019.8861868.

[13] E. Alazawi, M. Abbod, A. Aggoun, M. R. Swash, O. A. Fatah, and J. Fernandez, "Super depth-map rendering by converting holoscopic viewpoint to perspective projection," in *Proc. 3DTV-Conf., True Vis. Capture, Transmiss. Display 3D Video (DTV-CON)*, Budapest, Hungary, Jul. 2014, pp. 1–4, doi: 10.1109/3DTV.2014.6874714.

[14] T. Keskinen, V. Makela, P. Kallioniemi, J. Hakulinen, J. Karhu, K. Ronkainen, J. Makela, and M. Turunen, "The effect of camera height, actor behavior, and viewer position on the user experience of 360° videos," in *Proc. IEEE Conf. Virtual Reality 3D User Interfaces (VR)*, Osaka, Japan, Mar. 2019, pp. 423–430, doi: 10.1109/VR.2019.8797843.

[15] S. Partington. (2018). *What is Projection or Spatial Augmented Reality?* [Online]. Available: https://thearea.org/projection-augmented-reality/

[16] O. Bimber and R. Raskar, *Spatial Augmented Reality: Merging Real and Virtual Worlds*, A. K. Peters, Ed. Boca Raton, FL, USA: CRC Press, 2005.

[17] *Le Petit Chef Brings Visual Mapping to the Restaurant Table—Visual System Solutions | Panasonic Business*. Business.Panasonic.Co.Uk. Accessed: Feb. 6, 2020. [Online]. Available: https://business.panasonic.co.uk/visual-system/le-petit-chef-brings-visual-mapping-to-the-restaurant-table

[18] ScullMapping. (2016). *Le Petit Chef—Dessert*. YouTube. [Online]. Available: https://youtu.be/LXyX-OvZlUg

[19] *EB-X41.Epson*. Accessed: May 2, 2020. [Online]. Available: https://www.epson.eu/products/pro jectors/mobile/eb-x41

[20] J. O'brien. (2019). *Best Cruise Dining Celebrity Edge Le Petit Chef*. [Online]. Available: https://thetravelwomen.com/blog/celebrity-edge-le-petit-chef-cruise-dining-guide/

[21] B. Cooper. (2018). *AR Displays Deliver Restaurants of the Future*. digitalsignagetoday.com. [Online]. Available: https://www.digitalsignagetoday.com/articles/ar-displays-deliver-restaurants-of-the-future/

[22] How Augmented Reality is Driving Innovation for Businesses. (Feb. 12, 2019). *Apogaeis*. [Online]. Available: https://www.apogaeis.com/blog/how-augmented-reality-is-driving-innovation-for-businesses/

[23] AR in the Food and Hospitality Industry. (Aug. 13, 2019). *Onirix*. [Online]. Available: https://www.onirix.com/learn-about-ar/ar-in-the-food-and-hospitality-industry/

[24] E. Koui, "Avant l'appétit: An augmented reality interactive menu that elevates the gourmet food experience," M.S. thesis, Rochester Inst. Technol., Rochester, NY, USA, 2017. [Online]. Available: https://scholarworks.rit.edu/cgi/viewcontent.cgi?article=10770&context=theses

[25] Y. Fujimoto, "Food appearance optimizer: Automatic projection mapping system for enhancing perceived deliciousness based on appearance," in *Proc. IEEE Conf. Virtual Reality 3D User Interfaces (VR)*, Osaka, Japan, Mar. 2019, pp. 927–928, doi: 10.1109/VR.2019.8797732.

[26] M. R. Marner, R. T. Smith, and B. H. Thomas, "Mapping 2D input to 3D immersive spatial augmented reality," in *Proc. IEEE Symp. 3D User Interfaces (3DUI)*, Arles, France, Mar. 2015, pp. 171–172, doi: 10.1109/3DUI.2015.7131755.

[27] S. R. Ellis and B. M. Menges, "Localization of virtual objects in the near visual field," *Hum. Factors, J. Hum. Factors Ergonom. Soc.*, vol. 40, no. 3, pp. 415–431, Sep. 1998.

[28] N. Sugano, H. Kato, and K. Tachibana, "The effects of shadow representation of virtual objects in augmented reality," in *Proc. 2nd IEEE ACM Int. Symp. Mixed Augmented Reality*, 2003, pp. 76–83.

[29] K. Hiratani, D. Iwai, P. Punpongsanon, and K. Sato, "Shadowless projector: Suppressing shadows in projection mapping with micro mirror array plate," in *Proc. IEEE Conf. Virtual Reality 3D User Interfaces (VR)*, Osaka, Japan, Mar. 2019, pp. 1309–1310, doi: 10.1109/VR.2019.8798245.

[30] S. Schmidt, "Interaction techniques for spatial augmented reality setups," Dept. Inform., Univ. Hamburg, Hamburg, Germany, Tech. Rep., 2016.

[31] S. D. Hardianti, B. Sugandi, and A. D. Futra, "Face recognition and smile detection as an appraisal of customer satisfaction instrument," in *Proc. Int. Conf. Appl. Eng. (ICAE)*, Batam, Indonesia, Oct. 2018, pp. 1–6, doi: 10.1109/INCAE.2018.8579368.

[32] G. Tontini, "Interaction of service attributes on customer satisfaction," in *Proc. IEEE Int. Conf. Qual. Rel.*, Bangkok, Thailand, Sep. 2011, pp. 244–248, doi: 10.1109/ICQR.2011.6031718.

[33] M. Slim, R. Kachouri, and A. Atitallah, "Customer satisfaction measuring based on the most significant facial emotion," in *Proc. 15th IEEE Int. Multi-Conf. Syst., Signals Devices (SSD)*, Hammamet, Tunisia, Mar. 2018, pp. 502–507.

[34] I. Talegaonkar, K. Joshi, S. Valunj, R. Kohok, and A. Kulkarni, "Real time facial expression recognition using deep learning," in *Proc. Int. Conf. Commun. Inf. Process. (ICCIP)*, 2019, pp. 3750–3758. [Online]. Available: https://ssrn.com/abstract=3421486, doi: 10.2139/ssrn.3421486.

[35] L. Zhang, Y. Yang, W. Li, S. Dang, and M. Zhu, "Research of facial expression recognition based on deep learning," in *Proc. IEEE 9th Int. Conf. Softw. Eng. Service Sci. (ICSESS)*, Nov. 2018, pp. 1–4.

[36] I. Lee, H. Jung, C. H. Ahn, J. Seo, J. Kim, and O. Kwon, "Real-time personalized facial expression recognition system based on deep learning," in *Proc. IEEE Int. Conf. Consum. Electron. (ICCE)*, Jan. 2016, pp. 267–268.

[37] (2017). *Emotion Recognition Technology Leads to Quantitative Data*. Annalect. [Online]. Available: https://www.annalect.com/emotion-recognition-technology-leads-to-quantitative-data/

[38] F. Luo, H. Huang, Y. Duan, J. Liu, and Y. Liao, "Local geometric structure feature for dimensionality reduction of hyperspectral imagery," *Remote Sens.*, vol. 9, no. 8, p. 790, Aug. 2017, doi: 10.3390/rs9080790.

[39] G. Shi, H. Huang, and L. Wang, "Unsupervised dimensionality reduction for hyperspectral imagery via local geometric structure feature learning," *IEEE Geosci. Remote Sens. Lett.*, vol. 17, no. 8, pp. 1425–1429, Aug. 2020, doi: 10.1109/LGRS.2019.2944970.

[40] Z. Li, H. Huang, and Z. Zhang, "Deep manifold reconstruction neural network for hyperspectral image classification," *IEEE Geosci. Remote Sens. Lett.*, early access, Dec. 21, 2020, doi: 10.1109/LGRS.2020.3042999.

[41] J. Liu, S. Yang, H. Huang, Z. Li, and G. Shi, "A deep feature manifold embedding method for hyperspectral image classification," *Remote Sens. Lett.*, vol. 11, no. 7, pp. 620–629, Jul. 2020, doi: 10.1080/2150704x.2020.1746855.

[42] S. Li and W. Deng, "Deep facial expression recognition: A survey," *IEEE Trans. Affect. Comput.*, early access, Mar. 17, 2020, doi: 10.1109/TAFFC.2020.2981446.

[43] M. G. Padalkar, M. V. Vora, M. V. Joshi, M. A. Zaveri, and M. S. Raval, "Identifying vandalized regions in facial images of statues for inpainting," in *Proc. ICIAP Workshops*, in Lecture Notes in Computer Science, vol. 8158, A. Petrosino, L. Maddalena, and P. Pala, Eds., Naples, Italy. Berlin, Germany: Springer-Verlag, 2013, pp. 208–217.

[44] P. Shah, M. S. Raval, S. Pandya, S. Chaudhary, A. Laddha, and H. Galiyawala, "Description based person identification: Use of clothes color and type," in *Proc. Nat. Conf. Comput. Vis., Pattern Recognit., Image Process., Graph.*, 2017, pp. 457–469.

[45] C. Bach and D. L. Scapin, "Obstacles and perspectives for evaluating mixed reality systems usability," presented at the Workshop MIXER Exploring Design Eng. MR Syst., Island of Madeira, Portugal, 2004.

[46] A. Dünser, R. Grasset, and M. Billinghurst, "A survey of evaluation techniques used in augmented reality studies," in *Proc. ACM SIGGRAPH ASIA Courses (SIGGRAPH Asia)*, 2008, pp. 1–13, doi: 10.1145/1508044.1508049.

[47] K. H. E. Kroemer, *Fitting the Human: Introduction to Ergonomics/Human Factors Engineering*, 7th ed. Boca Raton, FL, USA: CRC Press, 2017.

[48] *National Optical Astronomy Observatory: Quality Lighting Teaching Kit*. Accessed: Jul. 10, 2020. [Online]. Available: https://www.noao.edu/education/qltkit.php

[49] F. Leccese, G. Salvadori, and M. Rocca, "Visual ergonomics of video-display-terminal workstations: Field measurements of luminance for various display settings," *Displays*, vol. 42, pp. 9–18, Apr. 2016.

[50] C. Davis. (Dec. 18, 2019). *Projector vs. TV: Consideration to Eye Health. ViewSonic Library*. [Online]. Available: https://www.viewsonic.com/library/entertainment/projector-vs-tv-consideration-to-eye-health/

[51] H. Yamada, K. Moriyasu, H. Sato, H. Hatanaka, and K. Yamamoto, "Effect of brightness on speckle contrast and human speckle perception in laser projection systems," *OSA Continuum*, vol. 2, no. 2, p. 349, Feb. 2019, doi: 10.1364/osac.2.000349.

[52] X. Guo, Y. Hu, B. Zhao, and S. Lin, "Texture mapping based on projection and viewpoints," in *Proc. 5th Int. Conf. Digit. Home*, Guangzhou, China, Nov. 2014, pp. 173–179, doi: 10.1109/ICDH.2014.41.

[53] (2018). *Restaurant and Cafe Lighting. Lighting Equipment Sales*. [Online]. Available: http://lightingequipmentsales.com/restaurant-cafe-lighting.html

[54] Humanscale. (2017). *Infographics for the People*. [Online]. Available: https://www.johngrimwade.com/blog/2017/08/07/humanscale/

[55] N. I. A. Rahman, S. Z. M. Dawal, N. Yusoff, and N. S. M. Kamil, "Anthropometric measurements among four Asian countries in designing sitting and standing workstations," *Sādhanā*, vol. 43, no. 1, pp. 1–9, Jan. 2018, doi: 10.1007/s12046-017-0768-8.

[56] I. W. Taifa and D. A. Desai, "Anthropometric measurements for ergonomic design of students' furniture in India," *Eng. Sci. Technol., Int. J.*, vol. 20, no. 1, pp. 232–239, Feb. 2017, doi: 10.1016/j.jestch.2016.08.004.

UDAYA DAMPAGE (Senior Member, IEEE) is an Engineering Consultant, a Platinum Grade Inventor, and a Senior Lecturer with the Faculty of Engineering, Kotelawala Defence University, Sri Lanka. His research interests include renewable energy integration, NextGen networks, virtual elephant barrier, agriculture 4.0, and smart grid. He is a fellow of the Institution of Engineers, Sri Lanka. He was conferred with Presidential Awards for his inventions, in 2016.

D. A. EGODAGAMAGE received the B.Sc. degree (Hons.) in electronics and telecommunication engineering from the Faculty of Engineering, Kotelawala Defence University, Sri Lanka, where he is currently pursuing the master's degree. His current research interests include projector-based spatial augmented reality and 3D projection.

A. U. WAIDYARATNE received the B.Sc. degree (Hons.) in electronics and telecommunication engineering from the Faculty of Engineering, Kotelawala Defence University, Sri Lanka, where she is currently pursuing the master's degree. Her current research interest includes deep learning-based facial expression recognition.

D. A. W. DISSANAYAKA received the B.Sc. degree (Hons.) in electronics and telecommunication engineering from the Faculty of Engineering, Kotelawala Defence University, Sri Lanka, where he is currently pursuing the master's degree. His current research interest includes smart restaurants.

A. G. N. M. SENARATHNE received the B.Sc. degree (Hons.) in electronics and telecommunication engineering from the Faculty of Engineering, Kotelawala Defence University, Sri Lanka, where he is currently pursuing the master's degree. His current research interest includes customer satisfaction monitoring.