TradAR : An Augmented Reality Companion For Exploring Local Culture And Language

Narahari Kohitha
Department of CSE
Velagapudi Ramakrishna Siddhartha School of Engineering
Siddhartha Academy of Higher Education
Vijayawada, India
kohitha.narahari@gmail.com

Dr K Praveen Kumar
Department of CSE
Velagapudi Ramakrishna Siddhartha School of Engineering
Siddhartha Academy of Higher Education
Vijayawada, India
praveenman@gmail.com

Chilakapati Reshma Chowdary
Department of CSE
Velagapudi Ramakrishna Siddhartha School of Engineering
Siddhartha Academy of Higher Education
Vijayawada, India
chilakapatireshmachowdary@gmail.com

***Abstract*—Tourists visiting unfamiliar places always face problems related to linguistic and cultural dissimilarities, as well as the scarcity of correct information about heritage sites. In order to resolve these problems, TradAR, a mobile application utilizing Augmented Reality technology, is proposed to improve the tourist experience. The proposed system provides a platform for real-time linguistic translation, cultural support, and AR-based services. TradAR includes three main translation services: Voice Translator, Text Translator, and Camera Translator. These services help tourists to communicate effectively in unfamiliar environments. The Voice Translator service enables the interpretation of spoken words, while the Text Translator and Camera Translator services help in the interpretation of written words and signboards, respectively. The proposed system also includes a Language Buddy service, which provides tourists with frequently used words and phrases in the local language.The ”Cultural Guide” section provides users with information about local culture, etiquette, and behavior, thus encouraging users to interact with local communities in a respectful manner.A notable feature of the system is the AR Heritage module, which allows users to access interactive 3D models, historical content, and information about heritage locations in real-time. This enables users to gain a better understanding of the heritage locations and thus allows for a more immersive experience with the cultural sites.The proposed system utilizes translation technologies and cultural awareness tools along with AR visualization to provide users with a more inclusive and interactive tourism experience. The proposed system not only assists users in overcoming communication barriers but also provides users with a cultural appreciation experience, thus making the tourism experience more inclusive and meaningful for users from different linguistic backgrounds.**

***Index Terms*—Augmented Reality, Tourism, Voice Translation, Cultural Etiquette, Sign Translation, Language Learning, AR Travel Companion**

I. Introduction

Tourism is an important factor in the promotion of cultural diversity and economic growth globally. However, tourists encounter a number of challenges when visiting new places, especially in countries with diverse cultures and languages. Language difficulties can impede a tourist’s understanding of signboards, interacting with local communities, and reading historical content at tourist sites. In addition, a lack of cultural, etiquette, and behavioral knowledge can lead to a situation where tourists unknowingly disrespect local communities. Conventional tourism sources, like guide books, non-interactive signboards, and human tour guides, are limited in providing information, as well as being non-interactive in assisting tourists.

With the recent advancements in Augmented Reality (AR) and Artificial Intelligence (AI) technology, there are opportunities to overcome these challenges in an effective manner. Augmented Reality technology provides a platform to add digital content to physical environments, enabling users to access information in a dynamic manner. At the same time, there are advancements in natural language processing and translation technology to enable real-time communication in different languages. However, existing solutions are mostly limited to individual functionality, such as translation and augmented reality visualization, without a comprehensive approach to integrating communication, cultural, and heritage experiences. The major contributions of this article are as follows

- An integrated Augmented Reality (AR) based tourism assistance system is proposed to incorporate multilingual translation, cultural information, and interactive heritage visualization in a single mobile application.
- Real-time voice, text, and camera translation is provided by incorporating artificial intelligence-based natural language processing and optical character recognition (OCR) technology, thereby addressing the language barrier of tourists.
- An interactive Augmented Reality (AR) based heritage visualization system is proposed to provide 3D recon-

structed models and historical information of real-world heritage sites, thereby enhancing cultural engagement and providing an immersive learning experience.
- The application provides a responsible and inclusive tourism experience by incorporating cultural information and behavioral insights from various regions.

II. Literature Review

Ronald T. Azuma, in his foundational survey [1], has given a definition of AR systems as ”those systems that bring together real and virtual worlds, interact in real time, and have accurate registration in 3D.” He also discussed the fundamental elements of AR systems, which include display systems, tracking systems, rendering systems, and calibration systems, which are necessary for effective AR system implementation. He also discussed the applications of AR systems, including medical visualization, military simulation, and education, along with the challenges that must be overcome, including registration accuracy and system latency. However, the survey was mainly focused on the fundamental concepts of AR systems and not on the features of AR systems, including multilingual communication and cultural support for tourism applications.

Mark Billinghurst et al. [2] surveyed various Augmented Reality (AR) technologies with a specific emphasis on human-computer interaction and user experience. The study covered various Augmented Reality hardware platforms and interaction mechanisms like gestures and multimodal interaction. The authors also discussed usability aspects and the need for an efficient interface for user interaction. Though the study offered significant insights into human-computer interaction in Augmented Reality systems, there is no mention of translation and culture assistance for a tourism-based application.

A comprehensive review of Augmented Reality technology, system architectures, and their application domains has been presented by Julie Carmigniani et al. in their paper ”Augmented Reality Technologies, Systems, and Application Domains,” with a specific focus on the integration of multimedia. In their paper, the authors have discussed the fundamental constituents of Augmented Reality, namely tracking, rendering, and interaction, as well as the different forms of Augmented Reality, including markers and location-based Augmented Reality. Furthermore, the potential of Augmented Reality in improving visualization and learning has been emphasized, especially in the domain of cultural heritage. However, the authors have not discussed features like multilingual communication and cultural support.

Tobias Höllerer and Steven Feiner [4] developed a mobile Augmented Reality system. This technology integrated location-based computing with real-time visualization. This technology was found to be beneficial in terms of providing contextual information to users in unfamiliar locations. This technology improved user navigation. Even though this technology was found to be beneficial in terms of tourism, there was no mention of providing multilingual support or etiquette.

Georg Klein and David Murray [5] have developed the Parallel Tracking and Mapping (PTAM) algorithm to increase the performance of real-time camera tracking and mapping in Augmented Reality (AR) systems. The algorithm divides the processes of tracking and mapping, performed simultaneously, to increase the performance, especially for systems with low processing power. This is a major step forward in the stability of marker-less Augmented Reality systems. However, the article mainly discusses the various methodologies of tracking and does not cover the various application possibilities. Javier Civera et al. [6] have developed MonoSLAM, a method to enable real-time localization and mapping using a single camera. The method makes use of probabilistic filtering to track the features and dynamically update the map. This method has increased the possibilities of implementing Augmented Reality (AR) systems in various devices, as it is not necessary to use special cameras. However, the article does not cover the various possibilities of the application.

Zhengyou Zhang [7] presented a flexible camera calibration technique that ensures precise camera parameter estimation using planar patterns. This technique simplifies camera calibration while ensuring high accuracy, and it is applicable in Augmented Reality (AR) systems. Camera calibration is a crucial aspect of ensuring precise alignment between virtual and real-world objects. Nevertheless, this study is mainly based on camera calibration techniques and does not discuss user-oriented Augmented Reality (AR) applications.

Davide Scaramuzza and Friedrich Fraundorfer [8] presented an overview of visual odometry techniques, which are useful in determining camera movements using sequential images. This ensures precise camera movement tracking without depending on external navigation, thus contributing to the stability of Augmented Reality (AR) systems. This study discussed various techniques, including feature detection and motion estimation algorithms, which are crucial in Augmented Reality (AR) system implementation. Nevertheless, this study is mainly based on motion estimation techniques and does not discuss user-oriented Augmented Reality (AR) in the context of tourism.

Moreover, Yonghui Wu et al. [9] proposed an introduction to Google’s Neural Machine Translation (NMT) system. This system includes the use of deep learning to improve the accuracy of translation. This system enables real-time multilingual communication. However, the system lacks the inclusion of AR-based visualization and cultural guidance. Thus, the system is limited to the processing of languages.

Moreover, Roxana Boboc et al. [10] proposed a review on the application of Augmented Reality in the context of cultural heritage and tourism. The proposed system demonstrated the application and benefits of AR in enhancing user experience through digital reconstruction and storytelling. The system also demonstrated an analysis of various AR frameworks for heritage-based applications. Although the system demonstrated significant benefits in the context of AR, the system lacks the inclusion of multilingual translation and cultural guidance.

The analysis demonstrates that the existing systems are limited to individual aspects, such as AR tracking, SLAM, camera calibration, and translation. However, there is a significant gap in the integration of these technologies to provide an efficient system for real-time multilingual communication, AR-based visualization, and cultural guidance. This gap in existing technologies has led to the proposed TradAR system.

In order to provide a clear framework of comparison for the aforementioned methods, a list of primary objectives, technical methodologies, and limitations of existing solutions is provided in Table 1. It is evident from this analysis that, while significant advancements have been made in various fields such as AR tracking, SLAM, camera calibration, and neural translation, these solutions are mostly available in standalone solutions and there is a lack of a unified framework that incorporates real-time multilingual translation, OCR-based environmental text recognition, SLAM-based markerless visualization of augmented reality, and culturally adaptive recommendations in a single mobile solution. This gap in existing research is where this proposed TradAR system aims to fill in.

III. Proposed Work

The proposed system, **TradAR (Traditional Augmented Reality Companion)**, is an intelligent mobile-based tourism support system that incorporates the concepts of Augmented Reality (AR) and Artificial Intelligence (AI) along with translation technologies and cultural awareness support in a unified platform. The main aim of the proposed system is to eliminate language barriers and provide proper context awareness about the heritage site with the help of immersive technologies like AR.

Generally, tourists face many problems during their visit to a new place, such as the ability to understand the local language, cultural awareness, and proper context awareness about the heritage site or monuments. Existing tourism applications provide only a few functionalities for the tourists, such as language translation and retrieving information from the web based on the current location of the tourist. However, the proposed system provides a unified platform for the tourists by incorporating the concepts of AI and AR.

The proposed system is designed by considering a modular approach that incorporates the concepts of real-time translation services, augmented reality visualization, and context-aware cultural recommendations. The proposed architecture consists of four layers:

- **User Interaction Layer**
- **Intelligent Translation Engine**
- **AR Heritage Visualization Module**
- **Cultural Knowledge and Recommendation Module**

The overall architecture of TradAR follows a layered design approach that enables scalability, modularity, and efficient processing across mobile devices. The architecture of TradAR consists of several modules, which work in collaboration to provide intelligent tourism services. The User Interaction Layer receives user input from text, voice, and camera-based interfaces. This input is then processed by the Translation Engine, which uses speech recognition, OCR-based text recognition, and neural machine translation. The AR Heritage Module uses computer vision and spatial mapping to locate monuments and provide interactive 3D models along with relevant information. Simultaneously, the Cultural Knowledge Module retrieves etiquette tips and cultural information from a structured knowledge base. All modules are controlled by a centralized control mechanism.

TABLE I
Comparison of Existing Approaches in AR Tourism and Translation Systems

Reference	Primary Focus	Key Technologies	Limitations
[1]	AR System Fundamentals	Real-time AR Rendering, Tracking	No tourism-specific application
[2]	AR Interaction Systems	Human-Computer Interaction, AR Interfaces	No tourism or translation modules
[3]	AR Technologies and Applications	AR frameworks, computer vision	No tourism assistance features
[4]	Mobile AR Systems	Location-based computing, mobile AR	Limited interaction with cultural data
[5]	AR Tracking and Mapping	PTAM, Feature tracking	No translation or cultural guidance
[6]	Mobile AR Localization	MonoSLAM, camera-based tracking	No heritage visualization features
[7]	Camera Calibration	Camera geometry, calibration algorithms	Not designed for AR tourism applications
[8]	Motion Tracking in AR	Visual Odometry	Focused only on camera motion estimation
[9]	Machine Translation Systems	Neural Machine Translation	No AR integration
[10]	AR in Cultural Heritage	AR visualization, digital heritage reconstruction	Limited translation support
TradAR	Integrated AR Tourism Assistant	AR + OCR + NLP + AI + Translation APIs	Requires optimization for lower-end devices

A. Functional Modules

1) A. Multilingual Translation Module: The Multilingual Translation Module provides real-time translation of voice, text, and camera-captured content. This module helps tourists communicate effectively with local residents. This module helps tourists accurately interpret text-based information such as signboards, menus, and information boards at heritage sites.

The translation pipeline comprises the following stages:

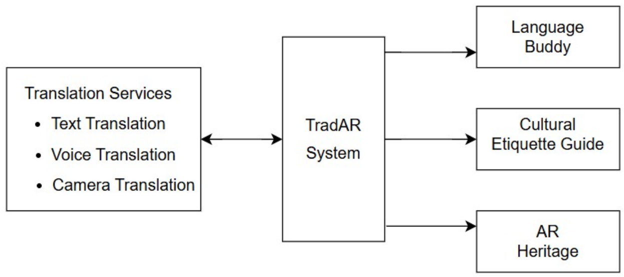

Fig. 1. Overall Architecture of the TradAR System

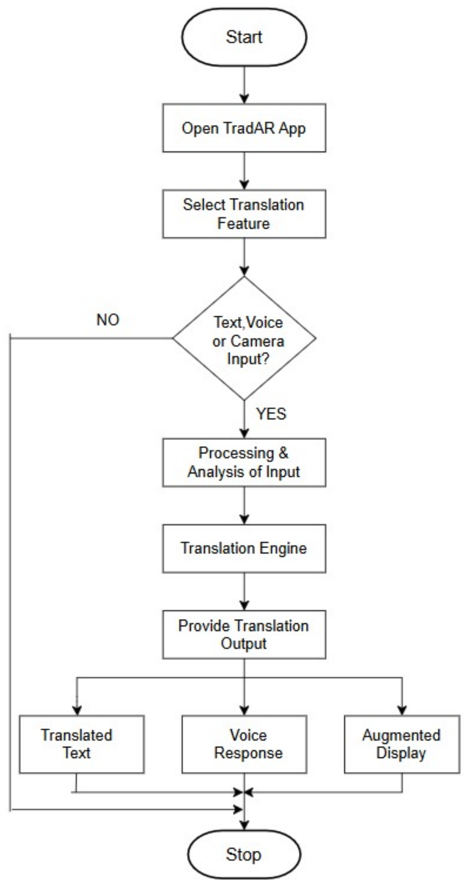

Fig. 2. Translation Processing Workflow in TradAR

- Acquisition of input from a microphone, keyboard, or camera
- Speech to text conversion of speech inputs
- Optical Character Recognition of text from camera images
- Automatic identification of languages
- Neural Machine Translation
- Rendering of output in text or speech

The speech recognition API is used to convert speech inputs into text, while optical character recognition is applied to camera images to obtain text from them. This text is then subjected to neural machine translation to obtain accurate translations. Furthermore, bidirectional translation is facilitated to enable efficient communication between tourists and local communities.

TABLE II
FUNCTIONAL COMPONENTS OF THE TRADAR SYSTEM

Module	Function	Technologies Used	Output
User Interaction Layer	Captures user inputs (voice, text, camera)	Mobile UI, Sensors, APIs	Input data stream
Multi lingual Translation Engine	Performs real-time language translation	Speech Recognition, Neural MT, Text-to-Speech	Translated text/speech
Camera Translation Module	Extracts and translates text from images	OCR, Image Processing, NLP	Translated visual overlay
AR Heritage Visualization	Displays interactive AR models of monuments	ARCore/ARKit, 3D Rendering	Augmented monument visualization
Cultural Knowledge Module	Provides etiquette and cultural guidance	Knowledge Base, Recommendation Engine	Contextual cultural suggestions
Location Awareness Module	Identifies nearby heritage locations	GPS, Maps API, Geolocation	Location-based recommendations

2) B. AR-Based Heritage Exploration Module: The AR Heritage Exploration Module allows for a more engaging experience for visitors by adding digital heritage information and three-dimensional model visualizations on physical monuments or historical landmarks. This module allows for a more engaging experience for visitors by adding digital heritage information and three-dimensional model visualizations on physical monuments or historical landmarks.

This module works in the following way: the computer vision system captures frames from the camera of a mobile device, which are then analyzed using feature detection algo-

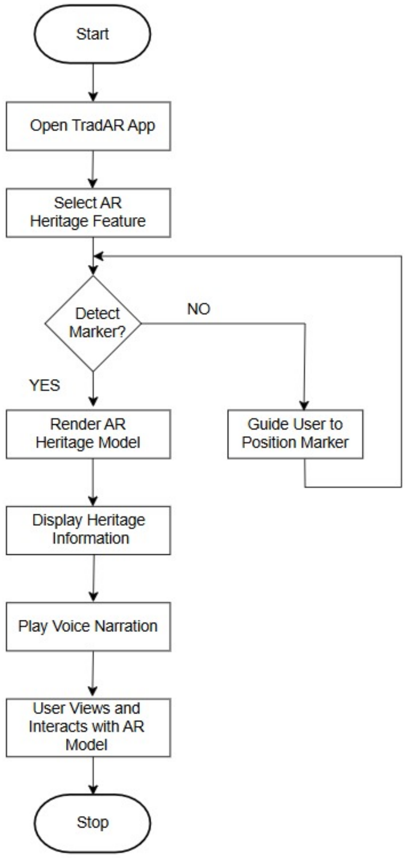

Fig. 3. AR Heritage Recognition and Visualization Process

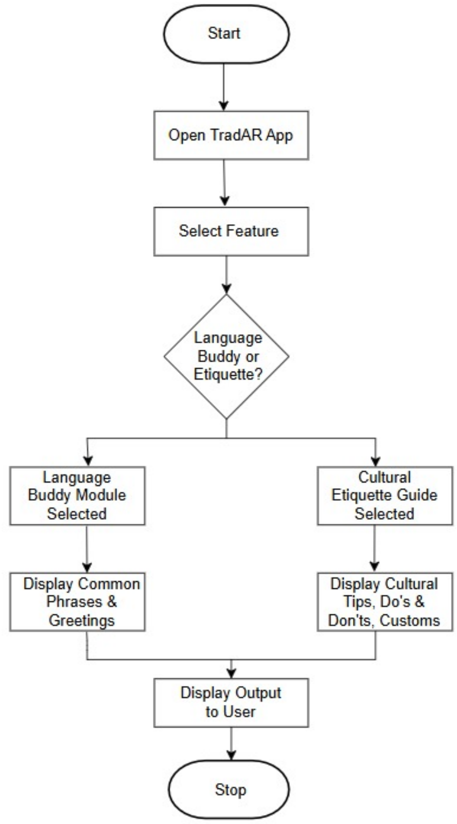

Fig. 4. Language Buddy and Cultural Etiquette Guidance Workflow

rithms to identify known monuments or landmarks. Once the detection has been made, the system retrieves the corresponding 3D model and metadata from the content repository.

By using the AR frameworks such as ARCore or similar spatial tracking systems, the system is able to perform surface detection, motion tracking, and environmental understanding to correctly position digital content in the physical environment of the user. The resulting visualization includes:

- Interactive 3D monument reconstructions
- Historical descriptions and annotations
- Cultural storytelling elements
- Guided exploration overlays

This module plays a crucial role in improving visitor engagement by enabling them to visualize the monument and obtain a better understanding of its cultural significance.

3) C. Cultural Etiquette Guidance Module: Cultural differences frequently cause misunderstandings between tourists and local communities. This is, however, addressed by the Cultural Etiquette Guidance Module.

The system utilizes a knowledge base that consists of cultural practices, etiquette, norms, and behavioral expectations in various geographic regions of the world. Based on the user's location and context of activity, a recommendation system is utilized to retrieve and provide cultural guidelines to the user.

Examples of guidance include:

- Appropriate greetings and gestures
- Dress codes for religious or historical sites
- Dining etiquette and social behavior
- Cultural festival information

By providing this guidance, TradAR promotes respectful interaction with local communities and supports responsible tourism practices.

B. Processing Workflow

TradAR uses a hybrid approach for the workflow process that balances the need for performance with computational efficiency by making use of on-device computation and cloud services.

When the user interacts with the system, the input manager determines the nature of the request and activates the appropriate system.

For the translation process, the following steps are part of the pipeline:

1) Capture user input (voice, text, or image)
2) Perform preprocessing such as noise filtering or image enhancement
3) Detect the source language using probabilistic language models
4) Apply neural machine translation

5) Render translated text or generate speech output

For AR-based exploration tasks, the workflow includes:

1) Capture real-time camera frames
2) Surface detection and spatial mapping
3) Detection of monuments by applying feature matching techniques
4) Retrieve the corresponding 3D model from the database
5) Align the model with the real-world coordinate system
6) Rendering the visualization
7) User interaction with the AR content

Performance optimization techniques such as asynchronous API calls and frame rate stabilization are implemented for the efficient working of the application on mid-range mobile devices.

C. Algorithm

Algorithm 1 TradAR Integrated Operational Workflow

1: **Input:** User interaction (Voice / Text / Camera)
2: Initialize translation engine and AR subsystem
3: Detect input modality
4: **if** Voice input detected **then**
5: Convert speech signal to text
6: Identify source language
7: Apply neural machine translation
8: Generate translated speech output
9: **end if**
10: **if** Camera input detected **then**
11: Capture image frame
12: Apply OCR for text extraction
13: Translate extracted text
14: Display translated overlay
15: **end if**
16: **if** Monument detected **then**
17: Retrieve associated 3D heritage model
18: Perform spatial alignment and light estimation
19: Render AR visualization
20: **end if**
21: Retrieve cultural recommendations
22: Present contextual guidance to the user
23: **Output:** Real-time translation and immersive AR assistance

IV. Results and Discussion

A. Overview

The TradAR: Augmented Reality-Based Cultural and Language Assistance System for Tourists was also tested to examine the functionality, response, and usability of the integrated components of this system. This system, based on translation APIs, OCR, speech recognition, and AR, provides real-time translation and cultural information to tourists. Some of the integrated components of this system, which were tested, are Text Translator, Voice Translator, Camera Translator, Language Buddy, Cultural Etiquette Guide, and AR Heritage Visualization. Various interfaces, such as text, speech, and camera, were used to test this system, and the test results show that all components of this system are integrated and working efficiently.

Fig. 5. Prototype of the System

TABLE III
SOFTWARE COMPONENTS AND THEIR PURPOSE IN TRADAR

Software / Component	**Purpose**
Android Studio	Integrated Development Environment (IDE) for designing, building, testing, and deploying the TradAR mobile application.
ARCore SDK	Enables markerless augmented reality functionality, which includes motion tracking, environmental understanding, and light estimation for real-time 3D heritage visualization.
Java/Kotlin	Primary programming languages for implementing the application logic, API management, translation workflow, and AR interaction mechanisms.
Google ML Kit (OCR)	Enables on-device optical character recognition for reading text from real-world objects such as signboards and museum plaques.
Neural Machine Translation API	It enables the implementation of transformer-based multilingual translation. This supports real-time voice and text translation.
Speech Recognition API	It helps in converting spoken language into text input.
Text-to-Speech Engine	It helps in generating translated text in a form of speech output. This supports bidirectional communication.
Firebase / Cloud Storage	It helps in storing 3D models, cultural knowledge sets, etc. This supports scalable data management.
Operating System	It needs Android OS version 8.0 and above, which supports ARCore-enabled mobile devices.

B. Experiment Setup

In order to provide an idea about the experimental environment, the software components are depicted in the following illustrated Tables IV.

Table IV: Software Components, Frameworks, and APIs Used for Developing, Integrating, and Executing TradAR App Modules

C. Experimental Results

(i) Home Page Interface

The TradAR home page offers a simple and intuitive user interface, allowing users to easily access all the functionalities provided by the system. The interface consists of the following features:

- Text Translation
- Voice Translation
- Camera Translation
- Language Buddy
- Cultural Etiquette Guide
- AR Heritage Module

This simple interface helps to increase usability and facilitates efficient navigation during travel.

(ii) Text Translation Performance

The Text Translator module translates any text entered by a user in real time. The translated output appears immediately, ensuring a high level of accuracy for daily travel needs such as menu cards, signboards, and information boards.

(iii) Voice Translation Performance

The Voice Translator module translates any text spoken by a user in real time. The system provides a high level of accuracy even in noisy conditions.

(iv) Camera Translation Performance

The Camera Translator module incorporates the use of Optical Character Recognition (OCR) technology to recognize and translate the content of real-world items such as:

- Signboards
- Menus from restaurant signs
- Posters

The system maintains a consistent performance level even with minor tilting and non-uniform lighting.

(v) Language Buddy Functionality

The Language Buddy module includes useful expressions that enable users to communicate effectively by providing a collection of commonly used expressions for:

- Greetings
- Polite expressions
- Requests

(vi) Cultural Etiquette Guidance

The Cultural Etiquette Guide provides cultural guidelines based on context, such as:

- Greetings
- Dress codes
- Social behaviors
- Cultural dos and don’ts

This module assists users in avoiding cultural faux pas and ensures a respectful and informed experience.

(vii) AR Heritage Module

The AR Heritage module utilizes a marker-based augmented reality technique to display a heritage site model in 2D/3D form. When a user scans a marker, a 2D/3D model is loaded using an ARCore technique. The augmented reality visualization consists of:

- Heritage model representation
- Textual description
- Voice narration to describe cultural significance

The augmented reality visualization is projected in the user’s physical environment and is accurately aligned with the physical marker, allowing users to interact with heritage structures.

D. Test Cases

To test the functionality and robustness of the proposed TradAR system, various real-life usage scenarios were implemented and tested.

(i) Scenario-1: Voice Translation – Normal Operation

The tourist utters a sentence in a language that is not understood by the locals to ask for directions. The system receives the audio correctly and translates it into the target language chosen by the tourist. The translation is done correctly and is also converted into speech for the tourist to listen.

(ii) Scenario-2: Camera-Based Translation

The tourist focuses the camera on a signboard that displays the name of a place in a language that the tourist does not understand. The system correctly recognizes the text on the signboard and translates it into the target language chosen by the tourist.

(iii) Scenario-3: AR Monument Recognition

The tourist uses the camera of the device to scan a heritage monument that is known to the tourist. The AR module correctly recognizes the heritage site and displays the 3D reconstructed image of the site with appropriate lighting and orientation.

(iv) Scenario-4: Cultural Guidance Trigger

If the user enters a culturally important area, the system recognizes the area and immediately displays relevant cultural etiquette guidelines such as appropriate dress and greeting etiquette.

(v) Scenario-5: No Monument Detected / Error Handling

If the camera is pointing towards an unknown object or the environment does not have enough feature points, the system does not display the AR image. Instead, it displays a notification saying ”Monument Not Recognized.”

(vi) Scenario-6: Text Translation Module

A tourist enters a sentence in an unknown language by clicking the ”Text Input” interface. The system processes the input and translates the sentence into the target language. The translated text is displayed immediately in the target language.

TABLE IV
TEST CASE SCENARIOS FOR TRADAR SYSTEM

Scenario	**Description**	**System Output**	**AR / Translation Status**	**User Action**
Voice Translation	User speaks foreign sentence.	Accurate translated text and audio generated.	Translation successful, low latency.	User communicates effectively.
Camera Translation	Camera captures foreign signboard text.	Translated text displayed as overlay.	OCR + translation successful.	User reads translated content.
AR Monument Recognition	Camera scans registered monument.	3D model rendered with contextual info.	AR alignment successful.	User interacts with AR model.
Cultural Guidance Trigger	User enters culturally sensitive location.	Etiquette guidelines displayed.	Recommendation module activated.	User follows suggested norms.
Monument Not Recognized	Camera points to unrelated object.	Displays "Monument Not Recognized".	Graceful failure handling.	User adjusts camera or scans valid site.

(vii) Scenario-7: Language Buddy Assistance

A tourist clicks the "Language Buddy" interface to get information about local language expressions that can be useful for communication with the local population. The system displays a list of useful expressions that a tourist may need during his/her visit. When a tourist clicks a phrase from the list, the system displays the translated text and pronunciation of the phrase by the "Text-to-Speech" module.

Table IV presents the detailed test case scenarios for TradAR.

V. CONCLUSION AND FUTURE WORK

TradAR is a major leap forward in the evolution of modern tourism, bringing together Artificial Intelligence (AI), Augmented Reality (AR), and cultural computing in a highly user-friendly mobile application. The application helps tourists visit new places with greater confidence, clarity, and cultural understanding. In addition, it successfully addresses the major problems tourists face when visiting new places, including communication difficulties, lack of access to relevant information, and cultural miscommunications, through the effective integration of translation modules, AR-based heritage visualization, and a rich Cultural Guide. The application also helps tourists become more aware of the importance of accessible heritage and the importance of good tourism practices, including cultural awareness and understanding.

Future plans include further improving the functionality of the platform by incorporating advanced features in offline translation, improving the accuracy of AR markers, and incorporating voice-assisted storytelling to provide users with a richer experience. Other features that are in the works include improving multilingual support, enhancing cultural knowledge, optimizing 3D models to provide a realistic experience, and providing users with recommendations based on their preferences and travel history. With these features, TradAR has the potential to become a digital travel companion that provides users with a richer cultural experience, facilitates communication, and provides users with an engaging learning experience.

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