Virtual Tourism and Digital Heritage: An Analysis of VR/AR Technologies and Applications

Muhammad Shoaib Siddiqui, Toqeer Ali Syed, Adnan Nadeem, Waqas Nawaz, Ahmad Alkhodre
Faculty of Computer and Information Systems, Islamic University of Madinah
Madinah, Kingdom of Saudi Arabia

***Abstract*—During the time of the pandemic, travel restrictions have impacted the tourism industry with an estimated loss of more than a trillion USD; however, at the same time, we have seen a significant increase in profits for the industries which empower remote connectivity. Various studies have identified the positive impact of virtual tourism, in which tourists can be attracted by providing a VR/AR-based experience of the destination. Similarly, virtual, mixed, and augmented realities are being used to enhance user experience in digital heritage and its preservation. With emerging technologies and increasing demand for e-tourism (due to travel restrictions), there is a need to review the technological changes and analyze user requirements with respect to virtual tourism. This paper provides a literature review of the latest technologies and applications that can potentially benefit the virtual tourism and digital heritage industry. We also provide an analysis of its impact on user experience, awareness, and interest, as well as the pros and cons of virtual experiences, which may benefit the research community about the current spectrum of virtual tourism and digital heritage.**

Keywords—Virtual tourism; digital heritage; virtual reality; user experience

I. Introduction

Virtual Reality (VR) [1] is the art of envisaging the imagination capabilities of the human mind. People can visualize and interact with imaginary objects in a fantasy environment. They can pretend to live, roam, and interact in ideal, purpose-built, or inventive worlds. In general, it is non-trivial to define limits on human imagination, however, it is possible to create human-inspired imaginary worlds with the state-of-the-art technologies in computer-based systems [2]. With the advent of technology, the imagination of the virtual world can be diversified with the real world to provide more realistic experiences. This field is known as Mixed Reality (MR) [1], in which a mixture of real world and virtual objects and scenes can be emulated to provide a better and more realistic experience. Similarly, the real world can be augmented with virtual assets and entities for providing past and future experiences, in-depth infographics, and supplementary details. This type of environment is termed as Augmented Reality (AR) [3].

During the pandemic, most countries posted a ban on traveling, which had an adverse effect on the tourism industry [4]. The tourism industry was estimated to be USD 1.478 billion-dollar industry worldwide [5] before the pandemic; however, due to the COVID restrictions, the severe effects were not limited to internal and external tourism but also propagated to other related industries such as hotels, restaurants, theme parks, travel agencies, etc. Tourism and related industries are estimated to observe a Trillion USD loss in 2021 and 2022 [6].

Virtual Tourism (VT) provides ample opportunity and a substitute for the tourism industry. For the safety of the public, people were advised to keep a distance from each other, which introduced boring and monotonous experiences in everyday life. VT enables a tourism experience within the boundaries and guidelines of the pandemic restrictions. Users can have an immersive experience of a virtual or a real environment using special equipment from the comfortability of their homes. Although the user interaction in a virtual environment is not real and limited, i.e., without the experience of culture and language; however, it provides a cost-effective solution with high-quality graphics and sufficient control on viewing details in a safe and secure environment. Another advantage of virtual tourism is the preservation of cultural and natural heritage from vulnerable environments, due to tourist visits and urbanization, which introduces a potential application of Digital Heritage (DH) [7]. Digital heritage is the use of digital media to understand and preserve cultural or natural heritage. The cultural, historical, scientific, educational, and linguistic resources are converted into digital media to be preserved for later generations. For example, if a historical site is visited more often by many tourists with poor maintenance, it may deteriorate its originality. Similarly, if an ancient book, is given physical access to many people, then the vital piece of history may get destroyed. Therefore, access to these resources should only be through virtual, augmented, and/or mixed realities to provide an immersive experience.

Virtual tourism and digital heritage are enabled by VR/AR/MR technologies and applications. Without the implementation and support of the right tools, this promising industry cannot develop and thrive. In this paper, we have reviewed various technologies and applications related to virtual, augmented, and mixed realities that play a vital role in VT and DH. We have conducted a survey analysis of the perceptions, experiences, and intentions of users of different age groups about virtual tourism and digital heritage. We have also presented an in-depth analysis of commercial technologies and web/mobile applications that would benefit the research community about the current spectrum of virtual tourism and digital heritage.

The rest of the paper is structured as follows. Section II provides a detailed introduction to virtual tourism, and digital heritage and its business value. Section III reviews the

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concepts, technologies and applications of VR/AR/MR. Section IV presents the analysis of our conducted survey about peoples' perceptions of VR & DH. Section V analyzes the pros and cons of VR & DH. Section VI provides the literature review of the research related to our domain and Section VII concludes the paper.

II. Virtual Tourism and Digital Heritage

The user experience in virtual, augmented, and mixed environments can be classified into non-immersive, semi-immersive, and fully immersive experiences. Due to the everyday interaction with the artificially generated and enhanced media, people do not consider the non-immersive experience as VR/AR/MR. People are accustomed to TV, mobile phones, and computer screens without realizing that they are having a non-immersive experience in the context of VR/AR/MR. This technology provides a computer-generated experience, but still gives users awareness and control of their physical environment. Non-immersive virtual reality systems rely on computer or video game consoles, displays, and input devices such as keyboards, locators, and controllers. Watching movies and playing video games are some examples of a non-immersive VR experience [8].

The semi-immersive environment provides users a more perceptive experience of being connected to the virtual world; however, they can still feel their physical surroundings. Semi-immersive realities use high-end computer graphics to provide a more realistic environment with limited interaction, such as, using tools and simulating to have a hands-on experience using controllers and feedback actuators. The applications of semi-immersive reality are mostly simulations, which partially replicate the design and functionality of real-world mechanisms, for training and educational purposes [8].

The most realistic and attractive experience is provided by the fully immersive realities. It provides the sense of touch using hand gestures and feedback actuators, sense of sound by using stereo-based and motion-based directional audio, and sense of sight by using motion and eye tracking sensors. Head-mounted 3D displays with directional sensors are used to provide a wide field of 360-degree stereoscopic view. This type of VR has generally been adapted for gaming and other entertainment purposes, but its use is also increasing in other fields such as education, training, and virtual tourism. With fully immersive experience, the potential for using VR/AR/MR is endless and only limited by human imagination [8].

All three categories of VR/AR/MR experience can be used to enable virtual tourism and digital heritage; however, they are limited by cost-effectiveness, in-depth design, technological evolution, and user acceptance [9].

A. Virtual Tourism

Virtual tourism is a remote application that enables travelers to explore nature, attractions, destinations, ruins, buildings, and other travel destinations without having to physically visit them. It provides a detailed experience made possible by the emerging technology. Virtual tours can include 360-degree photos, guided teleconferencing, virtual reality (VR), augmented reality (AR), video tours, the ability to interact with art and culture experiences, or ancient environments [10].

Virtual tourism is a growing trend around the world and it's not just a response to the COVID epidemic, it is being developed behind the scenes for quite some time. Traditionally used primarily as a marketing tool, virtual tourism has recently become increasingly popular among tourism industry stakeholders. Thanks to technological advances around the world and the use of the Internet, it is deeply rooted in the concept of smart tourism. Worldwide, the VT industry was worth USD 5 Billion in 2021 and it is anticipated to reach USD 24 Billion in 2022 [11], as shown in Fig. 1.

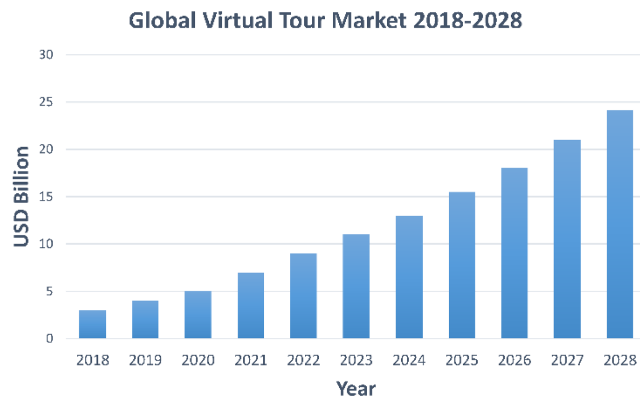

Fig. 1. Market Growth of Virtual Tourism [11].

Virtual tourism takes many forms and offers different levels of technical competence. In its simplest form, virtual tours solely rely on videos of places of interest. A 'tourist' uses speakers and a screen to see pictures. A more sophisticated form of virtual tourism involves immersing yourself in the environment using a headset or simulator. This may involve the use of various technological instruments, the user may need to wear gloves, and may have additional sensors, such as motion, proximity, direction, gestures, feeling (response), and even smell. Virtual tourism covers a wide range of digitally enhanced realities, including virtual reality, mixed reality, and augmented reality. For instance, whether you are a traveler looking for an exotic destination like Forest of Knives in Madagascar, a teacher sharing an experience with your students about the ruins of Machu Picchu, an architectural enthusiast looking for modern design like the Guggenheim in New York, or a wildlife explorer to spot animals from a safari jeep in Tanzania at sunrise, there is a virtual tour available for you.

Moreover, the virtual museum tour at the Louvre [12] provides access to Egyptian Antiquities, the remains of the Louvre's Moat, the Galerie d'Apollon, and famous artworks, such as, the Winged Victory of Samothrace, Mona Lisa, the Coronation of Napoleon, and many more. Dubai 360 provides an immersive awe-inspiring view of Dubai's modern architecture [13]. An interactive journey to the Great Barrier Reef, narrated by David Attenborough is available on YouTube 3D [14]. Users can have a semi-immersive experience of Anne Frank's house, walk through the Great Wall of China [15], indulge in the royal history at Buckingham Palace [16], experience a flight over a Volcano, bewildered by the scenic view of the Yosemite National park [17], imagine the gladiators' battle inside the Colosseum [18], inspired by the 360 view of the Statue of Liberty [19], visit the Holy land of Jerusalem [20] and Mecca [21], climb Mount Everest [22], get lost in the Amazon jungle, or even take a trip to space [23]. From the couch of your living room, you can party in Ibiza, be alone in the clouds in a hot air balloon, dive with fishes in the Georgia aquarium, or fly over the skies of Paris; virtual tourism enables all of this and much more [24].

B. *Digital Heritage*

The Charter on the Preservation of Digital Heritage of UNESCO defines digital heritage as embracing "cultural, educational, scientific and administrative resources, as well as technical, legal, medical and other kinds of information created digitally, or converted into digital form from existing analogue resources" [25]. UNESCO divides digital heritage into two separate groups namely Digital Cultural Heritage and Digital Natural Heritage [25]. Cultural heritage is the preservation and recording of cultural entities through digitization. These are things that are considered culturally important, which can be digitized or presented in physical details. It also includes intangible heritage, such as, traditions, customs, value systems, techniques, traditional dances, food, performances, and other unique features of culture, which are prone to destruction due to urbanization. Digital natural heritage is related to natural heritage objects of cultural, scientific, or aesthetic importance. In this case, digital heritage is used not only to provide access to these objects, but also to monitor changes such as plant and animal habitats over time.

There are several projects and programs which concentrate on digital heritage [27]. Global Digital Heritage (GDH) is a non-profit, private research and educational organization dedicated to documenting, monitoring, and preserving the global cultural and natural heritage [28]. They record, manage and provide immersive experiences to various destinations like Château de La Roche-Guyon in France, Early Christian Basilica of Sofiana in Italy, Archaeological Museum of Aidone in Italy; Bull Ring and Sanctuary of the Virgen de Las Nieves in Spain, Necropolis of Jebel al-Buhais in UAE, and many more [26].

Although a tour to the museum brings a surreal sensation of being in the past and present at the same time, feeling interested, surprised, happy, fantastic, and special because one can learn new things about the history and the art. Google Arts & Culture works with more than 1,200 museums and galleries around the world to provide everyone with virtual tours and online exhibits of the world's most popular museums [29]. Preserving the heritage by digitizing and making it available to the people is the main goal of such initiatives. Google Arts and Culture do not include all the museums and galleries; however, many of the museums, cultural sites, galleries, and even literature sites have created 2D and/or 3D models, which can be experienced through either virtual reality or augmented reality.

Similarly, history enthusiasts are able to visit various sites (Machu Picchu in Peru, stone carved palaces of Petra in Jordan, Taj Mahal in India, Khumbu Valley in Nepal, the Vatican City, etc.) [29], museums (Smithsonian National Museum of Natural History in USA, British Museum, etc.) [30] and read digitized old books at libraries (Library of Congress, British Library and UC Davis Library, etc.) [31] without disturbing the physical environment.

III. VR/AR Technologies and Applications

Virtual Tourism and Digital Heritage are enabled by VR/AR/MR technologies and applications [32] [33]. Without the implementation and support of the proper tools, this promising industry cannot evolve and prosper [34]. Various technologies are required for creating a virtual world, which involves capturing the real world, modelling the assets and scenes, and adding narration and interaction. For experiencing the virtual world, involves immersive displays, movement/motion tracking, environment sensing, and enabling runtime command and control. These technologies can be classified as, display screens, viewing glasses, sensors, cameras, image processing tools, and graphics processors. Furthermore, various software are also required to provide realistic experience, such as graphics engines, AR/VR toolkits, and libraries and APIs. In the following subsections, the models that envisages VT and DH, and some of the enabling technologies and application toolkits are discussed.

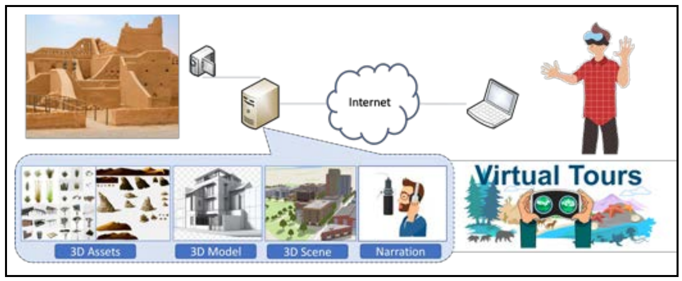

Fig. 2. Conceptual Model of How Virtual Tourism Concept is Created and Experienced.

A. *How VT and DH Works?*

Before the user can have a remote experience, the virtual environment must be created using CGI (Computer Graphics Interface). Fig. 2 shows a conceptual model of how the content is created for a virtual experience. For the non-immersive experience, a simple or 3D camera can be used to capture images and composed them together to create a visual tour using available toolkits and applications. 2D/3D assets are created using graphics tools, transformed into a 3D scene and then a virtual world is created. After that, narration is often added to guide the user.

For semi-immersive experiences, 360-degree cameras can be used which provide a panoramic view of the actual place. A user can connect to this 360-degree camera using the Internet and view it using a head-mounted display with motion sensors. When a user moves the sensors observe the movement and send to the controller, which calculates the viewing angle and direction and changes the display image accordingly. YouTube360 and Metaverse by Facebook are examples of these experiences.

Developers also use extensive CGI to create a 3D model of a place, such as, a palace or a museum, and augment it with the real images captured in real-time [35]. They use both audio and video streams to provide a fully immersive experience. The view in the 3D model is changed according to the movement of the user, which is recorded using gyroscope, magnetometer and accelerometer present in the head-mounted display or the mobile phone. Stereo surround-sound is used to provide directional sounds to the user with the built-in speaker in the head-mounted display. Similarly, for interaction with the environment, users can use a magnetic, ultrasonic, or gesture-based tracking systems to grab, and/or displace objects, actuate menus and/or perform other activities. The system receives the input signals, processes the interaction model, and displays the activities to the user at runtime. Instructions and detailed information about events, places, milestones, and important sites are also augmented in the 2D/3D world for guiding the users about the history or the significance of the place.

B. VR Equipment

1) Display devices: The quality of immersive in VR is defined by the display devices. A common monitor screen can provide a virtual experience; however, it would be a non-immersive impression [45]. A mobile phone can provide a semi-immersive experience, as it has motion sensors, which can detect changes in orientation and direction, and may respond by changing the view for the user [46]. The display devices use split screens to emulate a wide field of 360-degree stereoscopic view. This gives the user an illusion of looking around in the environment. Virtual Box [44] and Google Cardboard [43] are examples of such a device; however, they only provide a casing for the mobile device and help the user mount on the display device [44].

For a fully immersive experience, a range of head-mounted display devices are available, that contain sensors, cameras, location devices and controllers, built-in inside the device. Table I shows the comparisons of some of the famous head-mounted display devices, which are commonly known as VR kits.

As shown in Table I, Google Cardboard, and VRBox and similar devices are very cheap as they provide a method of holding a mobile phone for proper viewing the virtual environment. An elastic band is used to mount the device over user's head, or the user has to hold it using hands which makes it ergonomically infeasible. Some Bluetooth based controllers can be used to provide input; however, the experience in semi-immersive. On the other hand, HTC Vive Pro 2, HP Reverb G2, and Pimax Vision 8K X VR Headsets have ergonomic designs and are very comfortable with adjustable straps, which makes them very expensive. The other factors that make some of these devices expensive, is the display resolution and refresh rate. Pimax Vision 8K X VR Headset has the best display quality, however, high-quality CGI means an expensive GPU is also required. Every headset (in Table I) that is providing a fully immersive experience, requires a fast computer with a high-end GPU device except Oculus Quest 2, which can work as a stand-alone. It has its own processor and memory and can work with or without a computer. Oculus Quest 2 does not require extra devices, such as base stations, to track the headset and/or the controllers and provides flexible mobility using wireless communication. Oculus Rift, HTC Vive Pro 2, HP Reverb G2, HP Windows Mixed Reality, and Pimax Vision 8K X VR Headsets are connected through a wire to the computer; therefore, mobility is limited. However, wireless connectivity is being made available by various vendors to compete with the acceptability of Oculus Quest 2.

TABLE I. A COMPARISON OF VARIOUS HEAD-MOUNTED DISPLAY FOR VR

S. No	VR kit	Characteristics	Experience
1	Oculus Rift [36]	• Resolution 1280x1440, 80 Hz • No computation or memory resources • Accelerometer, proximity, magnetometer, gyroscope • Guardian system for headset and controllers tracking • Buttons and gestures-based input • Stereo speakers, positional audio • No Battery • Inexpensive	Fully immersive
2	Oculus Quest 2 [37]	• Stand-alone, • Resolution 1832x1920 per eye, 80 Hz • Qualcomm® Snapdragon™ XR2 processor with 128/256 GB ROM • Accelerometer, proximity, magnetometer, gyroscope • Guardian system for headset and controllers tracking, camera-based outside tracking, GPS • Buttons and gestures-based input • Stereo speakers, positional audio • 2–3-hour Battery life • Inexpensive	Fully immersive
3	HTC Vive Pro [38]	• Resolution: 2448x2448 per eye, 90/120 Hz, 5K display • 100-degree field of view • No computation or memory resources • G-sensor, proximity, gyroscope, IPD sensor • Guardian system for headset and controllers tracking, infrared camera-based outside tracking • Buttons and gestures-based input • Stereo speakers, positional audio • No Battery • Very Expensive	Fully immersive
4	HP Reverb G2 [39]	• Resolution: 2160 x 2160 per eye, 90 Hz, 2 LCDs • No computation or memory resources • G-sensor, proximity, gyroscope, IPD sensor • Guardian system for headset and controllers tracking and camera-based tracking • Stereo speakers, positional audio • No Battery • Expensive	Fully immersive
5	Sony Playstation VR [40]	• Resolution: 960x1080 per eye, 90/120 Hz • Graphics Controller Box for screen mirroring and sound processing • Accelerometer, gyroscope • Positional tracking with 9 LEDs via PlayStation Camera	Fully immersive

		• Stereo speakers, positional audio • No Battery • Expensive	
6	HP Windows Mixed Reality Headset	• Resolution: 1440 x 1440 per eye, 90 Hz, 2 LCDs • No computation or memory resources • Windows Mixed Reality inside/out 6 DOF motion tracking, gyroscope, accelerometer, and magnetometer • Front-facing camera tracking • Stereo speakers, positional audio • No Battery • Expensive	Fully immersive
7	Pimax Vision 8K X VR Headset [41]	• Resolution: 3840 x 2160 per eye, 60-114 Hz (2560x1440), 170-degree FOV • No computation or memory resources • 9-axis accelerometer • SteamVR tracking • Buttons and gestures-based input • Stereo speakers, positional audio • No Battery • Very Expensive	Fully immersive
8	DPVR Headset [42]	• Resolution: 1280x1400 per eye, 72 Hz, 110-degree FOV • No computation or memory resources • 3 DoF Non-positional tracking • SteamVR platform • No Battery • Very Cheap	Semi immersive
9	Google Cardboard [43]	• Uses mobile phone as a display • No computation or memory resources, • Very cheap	Semi immersive
10	VR Box [44] and similar	• Use mobile phone as a display • No computation resources, No memory, • Bluetooth based input devices are available • Inexpensive	Semi immersive

2) Sensors: A variety of sensor technologies are needed to provide input to VR/AR system. These sensors include object and motion tracking, directional sensing, visual sensing, and audio interfacing [46]. The technology is ever evolving by the introduction of new types of sensors and different types of haptics for touch, smell, and heat-based feedbacks. A conventional VR/AR system uses G-sensors, such as, accelerometer, magnetometer, and gyroscope to detect inertial movement and direction. Indoor and outdoor GPS systems are used to identify the location of the user, directional mics are used to understand what the user is saying or hearing and from where, and cameras are used to identify what the user is seeing. State-of-the-art devices are using more complex sensors, such as, time-of-flight sensors, heat mapping, structured light sensors, etc., which are product of integrated basic sensors mentioned above. Table II provides the details of some common sensors and tracking systems used in AR/VR technologies.

TABLE II. VARIOUS SENSOR USED IN AR/VR SYSTEMS AND THEIR USAGE

S. No	Sensor	Usage
1	Accelerometer	Movement tracking in X, Y and Z dimensions
2	Gyroscope	Sense angular velocity or rotation motion
3	G-sensor	Force of movement in gravitational units
4	Magnetometer	Direction tracking
5	Proximity	Measure distance of object in front
6	Light sensor	Measure the luminescence
7	IR sensor	Senses the invisible light (infrared) for proximity and motion detection
8	Depth sensors	Camera based sensor to detect the depth in the recorded image to identify which object is near and which is far away
9	Eye-tracking	Track the movement of eyes to identify where the user is looking
10	Directional microphone	A pair of mics which can identify where the sound is coming from using Doppler effect.
11	Inertial Measurement Sensor	An integrated accelerometer, gyroscope and magnetometer sensor
12	Time-of-Flight sensor	Laser or IR based distance detection for finding range between object and the camera. Used for robot navigation, vehicle monitoring, people counting, and object detection
13	Object & Gesture Tracking	Camera and image processing-based system used to track objects and user for recognition movement and gestures
14	Ultra-sound sensors	Ultrasound sensors are mainly used to detect proximity and distance
15	Thermal sensor	Helps in detecting heat signatures to differentiate between users and various objects.
16	Ambient light sensor	Helps in detecting heat signatures to differentiate between users and various objects.
17	GPS	Global Positioning System uses satellite-based location calculation and only works in open environments
18	Indoor GPS	To enable indoor location, Bluetooth or Wi-Fi beacon-based solutions are used where a device uses a triangulation method to calculate its own location

3) Cameras: The VR world is artificially created using CGI which can provide a 2D view for non-immersive display or a 3D view, which can be used to provide a fully immersive experience. But to create a whole 3D model, a lot of effort is required, which may not be realistic. To make the world more realistic, it is augmented by mixing the real-world object and scenes. Cameras are used to capture these images and then the virtual world is augmented with these captured images. Hence, the quality of the camera has significance in creating a realistic environment along with the 3D modelling and rendering process.

A simple camera can be used to take pictures of an environment from different angles and the images can be stitched together to provide a 360-degree view, which is time-consuming. These days, cameras are available that take a 360-degree picture of an environment and output a 3D world to be viewed at runtime or to be saved to create realistic mixed realities. A 3D camera is either omnidirectional or composed of many small cameras. It captures multiple images at the same time from different angles. The software, either inside the camera or on a computer or smartphone, orchestrates a spherical image by fusing the images. VR headset can be used to view these spherical images as it allows the user to move inside the image and feel an immersive experience. A comparison of some famous 360-degree cameras is provided in Table III.

TABLE III. COMPARISON OF FAMOUS 360-DEGREE CAMERAS

Q. No	Camera	Features
1	Insta360 One X2	• 2x 5.7K lenses • 6080x3040 360-degree recording • 6-axis gyroscope • 360 directional focus audio • Bluetooth, Wi-Fi, USB connectivity • MicroSD card storage • Less Expensive
2	GoPro Max	• 1x 5.6K lens • 16.6mp 360-degree recording • GPS • 4 channel microphones audio • Bluetooth, Wi-Fi, USB connectivity • MicroSD card storage • Less Expensive
3	Ricoh Theta Z1	• 2x 4K lenses • 23mp 360-degree recording • GPS • 6x microphones audio • Bluetooth, Wi-Fi (web server), USB connectivity • 50 GB internal storage • Expensive
4	Samsung Gear 360	• 2x 15mp lenses • 3840x1920 360-degree recording • Accelerometer, Gyroscope • Bluetooth, Wi-Fi, USB, NFC connectivity • Compatible with High-end Samsung Mobile phones • 1 GB internal storage with 128 GB using MicroSD • Cheap
5	Vuze XR	• 2 x Sony 12MP IMX-378 fisheye lenses • 3840x1920 360-degree recording through Ambarella H2 video processor • Accelerometer, Gyroscope • Wi-Fi, USB connectivity • 4x microphones • Removeable MicroSD card • Cheap
6	Nokia OZO	• 8 2Kx2K ISO 190-degree lenses • 9 Capture up to 12K30 x 12K30 Video/Stills • 500 GB SSD Module for Recording • Automatic stitching • HDMI output • Omnidirectional microphones • Extremely Expensive
7	Gopro Odyssey	• 16 x 2.7K Lenses • MicroSD card storage • Automatic stitching • USB cable for connectivity • 16-mono microphones • Expensive
8	Kandao Obsidian GO 360° 3D VR Camera	• 8 x 6K f/2.8 195° Fisheye Lenses • Capture up to 12K30 x 12K30 Video/Stills • Internal 8TB SSD Module for Recording • 8 x 6K f/2.8 195° Fisheye Lenses • Automatic stitching • Wi-Fi 6, Bluetooth 5, Gigabit Ethernet • 4-directional microphones • Extremely Expensive
9	Panono 360° 108MP Camera	• 6 x 3MP Cameras with 360° 108MP Still Image recording • Image Requires Stitching • Wi-Fi Connectivity • Expensive
10	Z CAM V1 Spherical VR 360 Camera	• 10 fisheye lenses with 190-degree view, each • 7K 360-degree video recording • Automatic stitching • Live video streaming • 4 built-in microphones • Very Expensive
11	Z CAM V1 Pro Cinematic VR Camera	• 9 MFT Lenses with 190-degree view • Automatic stitching • Live video streaming • 4-directional microphones • Extremely Expensive

4) Input devices: As with any system, user interaction is mainly based on the input devices being used. Although in VR most of the input is delivered through sensors; there are many input devices and controllers available for the users. Most of these input devices are only compatible with specific head-mounted displays, but some generic input devices are also available. Table IV presents some of the input devices that are being used by VR users and their classification based on the sensor technology they are equipped with.

TABLE IV. THE FAMOUS INPUT DEVICES OR CONTROLLERS FOR VR/AR KITS

S. No	Input Device	Class	Features
1	Oculus Controllers	Position and Orientation Tracking	IMU sensors, IR-Led- based tracking ring (for fingers) and camera-based hand tracking, HD haptic feedback, buttons and thumbstick
2	HTC Vive Controllers	Position and Orientation Tracking	24 IMU sensors, buttons, multi-function trackpad, dual-stage trigger, IR-based hand tracking, HD haptic feedback and a rechargeable battery
3	HP Reverb Controllers [39]	Position and Orientation Tracking	IMU sensors and active LEDs based tracking and IR camera-based hand tracking, haptic feedback, buttons and thumbstick
4	PlayStation VR Aim Controller [40]	Dual Camera-based Object Tracking	2x cameras, Hand tracking, gesture recognition
5	HP Windows MR Controllers	Position and Orientation Tracking	IMU sensors, multi-function trackpad and IR-led and camera-based hand tracking, HD haptic feedback, buttons and thumbstick
6	Polhemus Fastrak	Magnetic Tracker	3D digitizer and a quad receiver motion tracker, which computes the position and orientation of a small receiver
7	Mattel Power Glove	Acoustic (Ultrasonic) Trackers	Buttons, detects yaw, pitch and roll of hand, uses fiberoptic sensors to detect finger flexure to 256 positions per finger for four fingers. Uses sonics to calculate X, Y and Z location also

8	NAC Eye Mark Eye Tracker	Eye Tracking	Uses Pupil / Cornea Reflection to detect eyeball movement. Provides video footage of the field of view of the user in real-time
9	VPL Data Glove	3D input device: Glove	Camera and image processing-based tracking of the specific-colored glove to detect gestures as input.
10	Virtex Cyber Glove	3D input device: Glove	Uses electronic joint-angle sensors, electro-magnetic position tracker, and virtual hand control software detect gestures as input
11	Joystick based upon 6DOF	3D input device: mouse	Uses force-sensors to detect change in momentum and identify movement in all six directions.
12	Dexterous Hand Master (DHM)	3D input device: Dexterous manipulators	Extremely accurate movement and gesture-detection device used for medical and scientific training. Based on IMU sensors, position trackers and/or visual sensors.

C. Toolkits and Libraries

The tools and technologies are the building block of the virtual experience, and they are evolving with new features every day. They allow the user to have an immersive experience of the virtual or real world and provide a realistic interaction with the environment by constantly sending and receiving data from the devices to the multimedia system and vice versa. Another very important aspect of VR/AR systems is the 3D design and rendering model inside the server or mobile phone that enables this real-time interaction. These 3D realistic models and systems are created by graphic designers and software engineers using various programming frameworks.

To prompt development of 3D object and scene, various application and tools are available for the developers. For modelling object CGI tools, such as, 3D Studio Max, Maya, and Adobe Illustrator, are used. For building the scene and implementing the concepts of physics using complex mathematics of collision meshes, boundary detection, object interaction, differential equations, and fluid dynamics, the need for a support library is eminent. For prompt development, developer make use of 3D graphics engines, such as, Unreal Engine, Unity, Amazon Lumberyard, Unigine, if Tech 5, 3ds Max Design, ApertusVR, etc. These engines provide a VR SDK, which allows them to design, build, and test their VR environments.

Similarly, some toolkits are also available, which provide a quicker way to create VR games and environments [47]. They provide a collection of useful scripts, 3D assets and templates, interaction models, and libraries to interface various sensors, displays and actuators in a VR application.

VRSciT project provides a toolkit to explore new approaches in educational tourism using a VR environment [48]. TIDE Toolkit is a tourism toolkit for European Maritime and Underwater Cultural Heritage [49]. Digital Trail is another toolkit that allows developers to build their VR/AR content as an App and share the App with the users [50]. VITAKI is a toolkit designed to create VR applications and games with specific libraries for interaction with vibration and haptics [51]. VR Mini-Degree is another toolkit that provides tools to build VR games and applications using Unity. Samples of first shooter games, 360-degree space view and other examples are available to reduce the learning time for the developers. The tourism department in Northern Ireland has published a Cultural heritage toolkit for developing Irish cultural heritage experience for the tourists [77]. These are set of guidelines for developing virtual tourism systems. A similar toolkit is also published by Scotland [53] and a set of guidelines are published in [52] for promoting sports tourism.

For developing VR/AR systems, many developers are using VRTK, which is a VR toolkit for Unity Engine [47]. VRTK library consists of numbers of solution or mechanisms, like movement in VR, interaction with object like touching and catching, and 2D and 3D control like button, lever, and another objects. There are various libraries that provide ease in implementing tracking in AR/VR systems, such as, Qualcomm's Vuforia and ARToolKit, and the BuildAR authoring toolkits.

COLIBRI VR is an open-source VR toolkit for capturing, modelling, and rendering real-world scenes in a VR environment [54]. For visualizing data in an immersive environment, authors in [55] have developed a VR toolkit for building and analyzing datasets and processed results. OVR toolkit provides a desktop view in a VR experience by augmenting a VR environment with real-life desktop objects [56]. VR performance toolkit [57] provides models and algorithms to improve performance in VR-based games. POV's VR toolkit provides 3D assets and pre-build environments to create VR Apps in a matter of hours. Vrui VR toolkit provides functionalities, such as, portability, scalability, and fast development for VR applications. XR Interaction toolkit provides a cross platform, input, haptics, interaction, and feedback procedures for the VR environment. BlocklyXR is another toolkit which provides a visual programming environment for implementing realistic interactions in developing digital storytelling VR applications [58].

There are many other toolkits available for developers for visualizing data, developing educational applications and training exercises [59]. With time, better and powerful tools and technologies will be available for the developers to create highly immersive VR/AR/MR experiences.

IV. Survey Analysis

To identify the awareness of the field of virtual tourism and digital heritage among the users of the Internet, we opted to conduct a survey analysis. For better response, we limited our survey to less than ten (10) questions. The questions asked in the survey were all close-ended questions with mandatory responses. Table V shows the questions asked in the survey. We also identified the region from where the response was collected using the IP-based location services. We divided the responses according to the following regions: (1) Far east and south-east Asia (including Australia), (2) Central & south Asia, (3) Middle east & northern Africa, (4) Europe, (5) North America, and (6) Latin & south America. The survey was distributed through academic links; hence, most of the responses are from people who are associated with the education sector. We receive almost 550 responses, out of which 534 are valid responses.

TABLE V. SURVEY QUESTIONS AND THEIR POSSIBLE RESPONSES

Q. No.	Questions	Possible Responses
1	Gender	Female, Male, Not Specify
2	Age Group	Baby Boomers, Gen X, Millennial, Gen Z
3	Are you aware of Vitual Tourism?	Yes/No
4	Are you aware of Digital Heritage?	Yes/No
5	Have you ever experienced Vitual Tourism?	Yes/No
6	Have you ever experienced Digital Heritage?	Yes/No
7	Are you willing to experience Vitual Tourism?	Yes/No/May be
8	Are you willing to experience Digital Heritage?	Yes/No/May be

A. *Demographics of the Responses*

Demographics of the collected data is shown in Fig. 3. Out of the 534 responses, 21% identified themselves as male, 10% as female, while 69% preferred not to disclose their gender (shown in Fig. 3(a)).

For the age groups, 2% only identified themselves as Baby Boomers (above 56 years old), 17% as Generation X (43-55 years old), 44% as millennials (aged 30-42 years), and 37% as Generation Z (20-29 years old).

Region-wise, we got 16% responses from Far East and south-east Asia, 27% from central & south Asia, 21% from middle east & northern Africa, 16% from Europe, 13% from north America, and 7% from Latin & south America, as depicted in Fig. 3(b). The demographic results show that although the responses are not a lot, but the sample covers a major portion of the world population with people from all age groups.

B. *Awareness of VR and DH*

The awareness of existing applications for virtual tourism and digital heritage is shown in Fig. 4(a) and 4(b) respectively. In the overall scenario, more people are aware of virtual tourism than digital heritage. But comparatively, Millennials and Generation Z have more awareness than the older age groups. It happens because of the technological savvy nature of the younger generations.

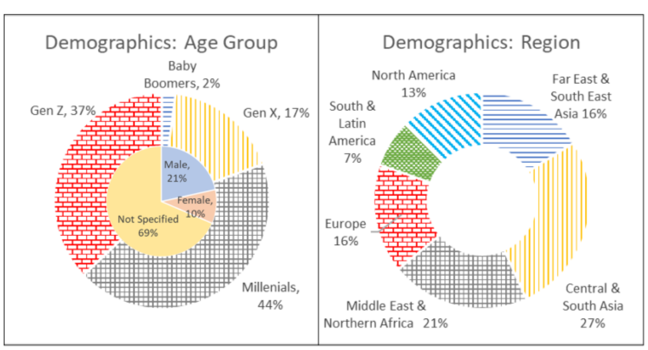

Fig. 3. Demographics of the Responses for the Survey. (a) Age Groups and Gender (b) Regions.

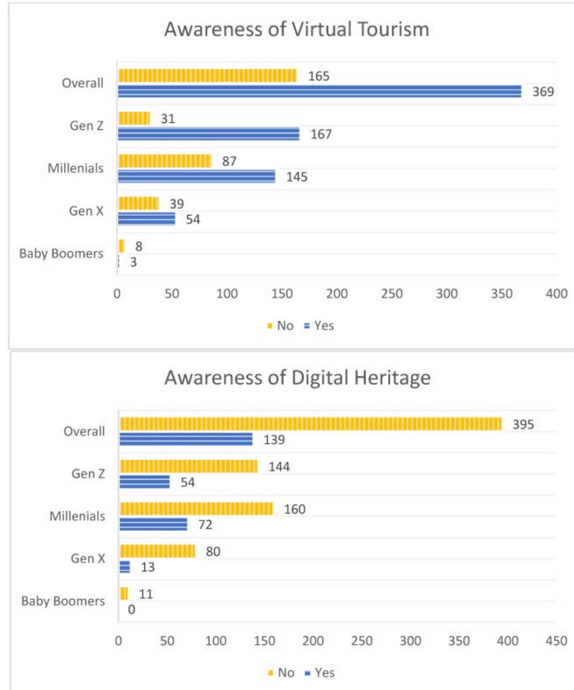

Fig. 4. Response Statistics about the Awareness of (a) Virtual Tourism and (b) Digital Heritage.

C. *Experience with VR and DH*

Fig. 5(a) and 5(b) show the results of the people who have actually experienced the virtual tourism and digital heritage applications, respectively. We see similar trends, as in Fig. 4. But if we compare the results of Fig. 4 and Fig. 5, we see that although many people are aware of the virtual tourism; however, fewer have experienced it.

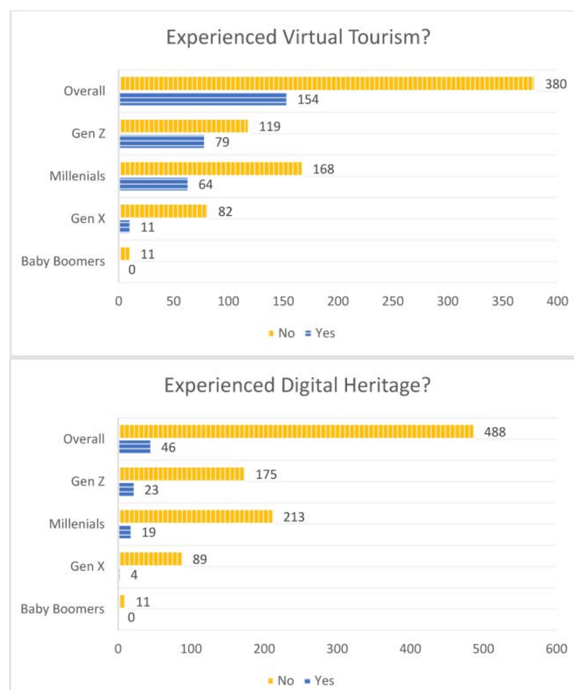

Fig. 5. Response Statistics about the How many People have Experienced of (a) Virtual Tourism and (b) Digital Heritage.

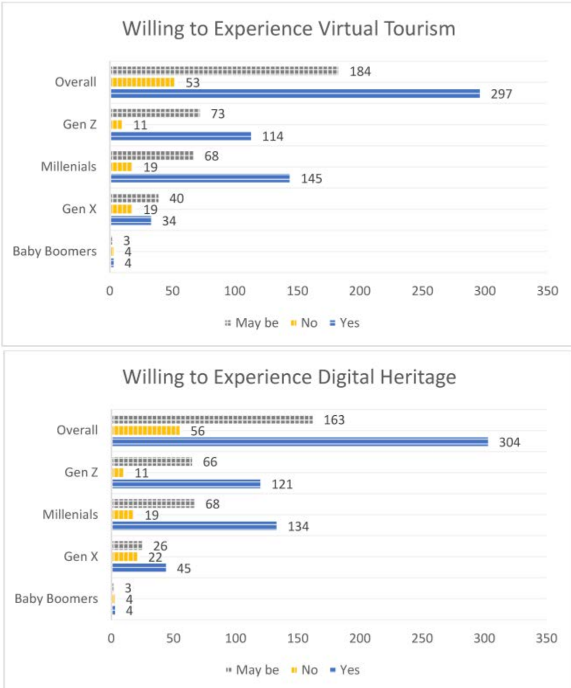

Fig. 6. Response Statistics about the How Many People have shown Willingness to Experience (a) Virtual Tourism and (b) Digital Heritage.

In case of digital heritage, the values are even lower. Again, the younger age group is more interested in the concept of virtual tourism as compared to the older age groups.

D. Willingness to Experience VR and DH

Finally, Fig. 6 shows the willingness of people to experience the applications of virtual tourism and digital heritage. It can be observed that most people have shown interest in the field, and they plan to visit the website and use applications that provide them with a virtual experience. However, many people still prefer the real traditional experience. The reasons that motivate people to experience the virtual environment or even the real environment with a remote axis are discussed in the next section. We also discuss the demerits of virtual tourism and digital heritage.

V. Pros and Cons of VR & DH

Although, there are many advantages of virtual tourism and digital heritage; however, the experience lacks certain supplementary aspects that have real importance and impact on the tourists. Some of these issues are discussed in the following subsections as advantages and disadvantages.

A. Advantages

1) Safety and security: One of the biggest advantages for the person who chooses virtual tourism over physical one is the safety and security of the individuals. Many tourist destinations are filled with cheaters and scammers and even kidnappers. There have been many incidents where people were abused mentally and physically [60]. VT provides a safe and secure experience from the protected home environment.

2) Control on view: In a VT, the users may have control over what they want to view and what they want to avoid. For example, some people are introverted and lack skills in interacting with other people and consider them as aliens, which helps them to avoid self-embarrassing behavior. VT allows the users to eliminate these experiences and focus on what they want to view and how they want to view the remote environment.

3) Cost effectiveness: Although tourism is one of the financially stable industries; however, not everyone is blessed with enough fortune to visit faraway places due to the cost of traveling, accommodation, and fares. VT and DH provide a feasible opportunity to the less privileged people as the virtual tourism cost considerably less than the traditional tourism. Though, the experience is not similar, but the users can save on cost by opting for VT. Some of the VTs are available free of cost for promotional purposes, while digital heritage sites are supported by governmental funding to make them accessible for free of cost.

4) Less impact on vulnerable destinations: Natures beauty is significantly destroyed whenever a location becomes a tourist spot. Tourism industry requires accessibility, accommodation, and utilities for the visitors. Hence, roads are made, hotels are erected and the people who visit later may damage the environment. In contrast, virtual tour can be recorded without endangering the environment and natural beauty can be preserved.

5) Preserve environment: The direct benefit of DH is the preservation of the cultural, historical, scientific, educational, and linguistic resources. For example, many artifacts lose their originality when tourists visit the historical sites. Likewise, access to ancient sculpture, sites, and books can destroy important parts and evidence of the history. Therefore, access to these resources is enabled via virtual, augmented and/or mixed reality.

6) Try before buy: VT provides the opportunity for tourists to first try the cheaper virtual experience before deciding to travel to the actual destination. This avoids or at least limits bad experiences for the travelers. They can try the virtual tour by experiencing it and make an educated decision to save time and money.

7) Permanent memory in high resolution: Everyone likes to take pictures and make videos of the place they visit. It helps them to recall their memorable moments and to capture the beauty and details of the visited places. VT and DH allow them to have high-quality pictures and videos of their experience. Furthermore, they can experience the environment again, anytime they want.

8) Visit the past, the present and even the future: With the Advent of virtual tours and digital heritage, a person is able to walk among dinosaurs, witness the landing on the moon and even walk on water. A user can experience the historical achievements of mankind and places which have been destroyed by time and urbanization. Similarly, a person can revisit his experience of the past, which s/he enjoyed with the loved one. Envisaging the human imagination, we can even visit the future world, which we want to create for our next generations.

B. Disadvantages

1) Lack of physical interaction: In real tourism, people share cultural knowledge and experience with other people through physical interaction by participating in the activities. When tourists visit any place, they take part in the cultural events, chat with the local people and gain valuable insights from their daily life. Such experience becomes long lasting, and they can share with other people effectively. Visiting and experiencing various diverse cultures improves humans' inter-personal skills. However, in a virtual experience, a user is not able to experience the diverse culture of the world and remain unknown of the fellow human beings.

2) Artificially enhanced scenery: Some of the virtual tourism application provide CGI (Computer-generated imagery) enhanced scenery, which is quite different from the actual environment or destination. Mostly, this is done to motivate the user for marketing purposes; however, this may come as fraud or intentionally mislead the users from reality. Therefore, some of the users may not opt for virtual tourism and prefer to physically visit the destination. In case, if a user witnesses such a difference experience, then user will be reluctant to experience virtual tours in the future.

3) Lack of relaxation: Some people travel for sight-seeing, as well as relaxation; however, the virtual tourism may not provide relaxation. On the other hand, some people feel tired after using the AR/VR systems due to the artificial visual movements. People who are claustrophobic or suffer from vertigo and epilepsy, would not be able to have a decent experience from the virtual tours.

4) Anti-globle village concept: The world is fast becoming a global village with technological advances, such as, fast travelling, Internet, social media, etc. People are becoming close to each other as they interact through these platforms. However, travelling is still the most significant way that makes people be a part of that global village. In virtual tourism, physical contact is missing, which enable the sense of being together. Younger generations are already distancing themselves from actual physical contacts and rely on online communication and the concept of VT will only augment this problem.

5) Change of environment: One of the most common reasons for travelling is a change in environment. Mostly, people have a busy schedule with consistent daily timetable, which they follow for months and years. They start feeling bored and wearied by this perpetual routine. Hence, they look for vacation with a change in scenery and itinerary in mind. Virtual tourism may create a change of experience for a few hours, but the minute change does not impact the person psychologically and they do not feel thrilled and animated.

6) Lack of availability to everyone: The technologies which are used to enable VT and DH are still expensive and their application is still not available for everyone to explore. Although most of the applications are free, but the cost of Internet and display devices/mobile phones (with high-end computer graphics) affects the availability of virtual tours.

7) Lack of financial gains: A tourist destination can earn a lot due to the visiting travelers through tickets, most of which is used for the management of the destination. At the same time, there are some supplementary industries that observe an increase in business due to the increase in travelling such as hotels, restaurants, travelling agencies, airlines and bus service, guides, etc. The concept of VT can reduce the numbers of tourists, which could have a severe impact on the earning of the tourist destination, as well as the supplementary industries.

VI. Related Work

In this section, we present similar works done by various researchers in the context of virtual tourism and digital heritage. In literature, we found different surveys and review papers [9-10] [27] [32-33] [61] [64-72] [74] discussing the feasibility, business value, social impact, marketing trends, technological evaluation, challenges, and issues. Other research articles [62] [63] [34] [73] [75-76] proposed diverse solutions pertaining to virtual, augmented, and mixed realities, while targeting virtual tourism and/or digital heritage. A brief statistical overview of existing studies in terms of citations and year of publication is provided in Table VI, which explore the surveys and reviews published in the field of virtual tourism and digital heritage. It is evident that most of the related works targeting virtual tourism as compared to digital heritage. Moreover, many people are citing the work done in VT, which shows lack of efforts in DH domain.

Verma et al. [10] has provided a comprehensive review of the literature related to virtual tourism with focus on the technologies, methodologies, and impact of VR/AR on tourism industry. They have also identified potential stakeholders and presented a quantitative and qualitative analysis of published research in tourism domain. Fan et al. [32] has analyzed the impact of immersive technologies on the virtual tourism by examining the social interactions and experience feedbacks from the users. Liang et al. in [61] reviewed augmented reality for tourism using cluster-based analysis with four empirical studies. They have based their recommendations on identified future directions to propose further investigation in the emerging area of gamification and explored the potential negative consequences of augmented reality. In [62], authors have explored the alternative ways of travelling during the pandemic and identified virtual tourism as a solution. The author of [9] has reviewed around 32 journal papers, published during the years 2000-2018, to not only identify the impact of VR and AR on virtual tourism but also suggested future directions. Similarly, Loureiro et al. [63] have used citation network analysis and text-mining to study 56 journal and 325 conference papers for identifying the requirements, challenges, solutions, and future trends in the field of virtual tourism using AR/VR technologies. Egger et al. in [64] have provided a literature review on AR/VR technologies and identified the strengths and weaknesses in the context of accessibility and marketing towards tourism.

TABLE VI. LITERATURE REVIEW OF THE VIRTUAL TOURISM AND DIGITAL HERITAGE REVIEW AND SURVEY PAPERS

Authors & Reference	Citations	Publication Year	Field
Verma et al. [10]	0	2022	VT
Fan et al. [32]	2	2022	VT
Liang et al. [61]	19	2021	VT
Riesa et al. [62]	5	2020	VT
Çeltek [9]	2	2020	VT
Loureiro et al. [63]	225	2020	VT
Egger et al. [64]	6	2020	VT
Pestek and Sarvan [69]	33	2020	VT
Loureiro and Correia [70]	4	2020	VT
Kononova et al. [71]	4	2020	VT
Beck et al. [65]	129	2019	VT
Yung and Khoo-Lattimore [66]	435	2019	VT
Wei. [67]	88	2019	VT
Claire and David [68]	84	2003	VT
Batchelor et al. [72]	4	2021	DH
Champion and Rahaman . [27]	21	2020	DH
Abdelhamid and Galal [73]	5	2019	DH
Bekele et al. [33]	411	2018	DH
Münster S. [74]	21	2017	DH
Münster et al. [34]	20	2016	DH
Tammaro and Maria [75]	10	2016	DH
Loannides et al. [76]	39	2014	DH

Beck et al. [65] have performed a comprehensive review on VR for tourism and discovered that the VR is complementing tourism as a marketing tool rather replacing it. However, this paper was published before the COVID pandemic and since then the trends have changed as suggested in [10]. Yung and Khoo-Lattimore, in their review paper [66], have identified various factors, methodologies, and class of virtual technologies that can benefit VT. They have also identified research gaps and potential tourism sectors in this field. A critical review is presented in [67] to understand the research progress on VR/AR in tourism and hospitality from 2000 to 2018. Based on the review of 60 journal articles, they have recommended research directions in VR/AR with their management. Authors of [68] have reviewed the existing and potential exploitation of Virtual Learning Environments (VLEs) within hospitality, leisure, sport, and tourism. Other research studies in [69], [70], and [71] provided short reviews on identifying enabling technologies of VR and AR in transition from tourism to e-tourism.

Bekele et al. in [33] have reviewed the trends in VR/AR/MR that can benefit the cultural heritage paradigm. They also identified application areas in digital cultural heritage and identified appropriate technologies for various digitizing cases in preserving heritage and culture. Batchelor et al. in [72] have presented a literature review on digital and smart heritage by identifying the requirements, challenges, and analyzing the complementary technologies. Champion and Rahaman in [27] provided a collection of websites and repositories on 3D model of heritage sites. They also reviewed various platforms that support the digital heritage and provided guidelines for future proofing and preserving the heritage using digitization. Authors in [73] have discussed digital freehand sketching, digital measurements, photographic techniques for creating panoramas, 3D models and interactive tours, interactive virtual tours, VR techniques and 2D and 3D model creation for legacy digitization and other trends. Similarly, researchers have provided various literature reviews that discuss the topics and research domains [74] and identified challenges and solutions for preserving digital heritage [34], [75], [76].

Review papers to analyze the AR/VR technologies in the field of virtual tourism are many; however, the technologies are changing with the advancements in sensing, tracking, and computing capabilities. We noticed a lack of interest and limited research work in digital heritage domain compared with virtual tourism. As digital heritage and environment for virtual tourism have similarity in media creation, interaction, and immersive experience; hence, a survey to review the AR/VR technologies and application for both VT and DH was missing. This paper has fulfilled this gap and provided a single knowledge source for people working in the blended domain.

VII. CONCLUSION

In this paper, we have reviewed and analyzed the concepts of virtual and augmented realities, which have a significant role in the field of virtual tourism and digital heritage. We have presented an in-depth analysis about the commercial technologies and web/mobile application, which can benefit the research community, especially, novice researchers in comprehending the current spectrum in the field of virtual tourism and digital heritage. We have presented the survey analysis of the awareness, experience, and willingness of using virtual tourism and digital heritage by the users of various age groups. The results have shown that the young generations are excited to experience these technologies. In the end, we also provide the advantages and disadvantages associated with virtual and remote tourism.

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