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Research Article

A Technology Survey on IoT Applications Serving Umrah and Hajj

Muhammad Binsawad[1] **and Marwan Albahar**[2]

[1]*King Abdulaziz University, Computer Information System Department, Jeddah, Saudi Arabia*
[2]*Department of Science, Umm Al Qura University, P. O. Box 715, Mecca, Saudi Arabia*

Correspondence should be addressed to Marwan Albahar; marwanalialbahar@gmail.com

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Emerging technologies provide a highly compatible platform for analyzing substantial data volumes relating to crowd management. These technologies are not only effective in providing remedial solutions but they are also cutting-edge, saving both time and money, and user-friendly. About twenty percent of the world's Muslims are granted the ability to take part in religious observances on an annual basis. An in-depth analysis of the technologies and applications used in the Hajj and Umrah systems is required given the importance of utilizing and adapting technology to assist pilgrims performing the Hajj and Umrah. Both of these pilgrimages are considered acts of worship by Muslims. As a result, the services provided during Umrah and Hajj will be significantly enhanced if the numerous technological advancements that are evaluated in this paper are implemented. The majority of previous research is shown to revolve around artificial intelligence and embedded Internet of Things technologies in the paper, highlighting a gap in the research that should be filled by investigating the necessity of discussing and introducing immersive technologies. During the annual pilgrimage to Makkah, Saudi Arabia, several different technologies are utilized with the goal of enhancing the quality of services provided to pilgrims performing the Umrah and Hajj. This paper provides an analysis of these technologies. The findings of this paper point to new research directions as well as a more realistic and practical approach to improving services during Umrah and Hajj.

1. Introduction

In recent years, the field of Internet of Things (IoT) technologies has advanced significantly in a variety of industries and spheres of human activity. Today, technological applications are essential to the growth and prosperity of people and nations across the globe and in sensitive services. Hajj is one of the five pillars of Islam and is an annual Islamic pilgrimage to the Saudi Arabian city of Makkah. Hajj is also referred to as a religious obligation that every physically fit and financially able adult Muslim must perform once every few years. When pilgrims from around the world reach the vicinity of the city of Makkah, they may be constrained by specific religious obligations [1]. In the context of Hajj, a large number of pilgrims must be efficiently managed due to a problem with crowd management that necessitates the use of technology [2]. The concept of crowd management is regarded as the most significant challenge facing Hajj and many other countries where large groups of people congregate. The procedure for controlling the flow of crowds has been described as an important and crucial concern, particularly when a matter or an accident causes panic [3]. Thus, the concept of the emergence of technologies could aid in the development of crowd management solutions for actual disasters. In the past few years, the world has witnessed a variety of crowd-related disasters, including the deaths of thousands of people. For centuries, Hajj has been one of the most crowded places because it annually attracts millions of pilgrims to congregate in one location. The Kingdom of Saudi Arabia has been working to serve and manage the pilgrims, and Hajj aims to provide the best possible safety and security measures with regard to the facilities used for crowd control [2]. Utilizing modern technology in crowd management may be the optimal way to overcome the challenge and dispose of the potential problem. In the last 10 years, the Internet of Things (IoT) has created a primary

transformation that has led to significant change in numerous fields, including business, health, and transportation [3]. The IoT ecosystem consists primarily of four elements: communication, user interface, data processing, and sensors. It enables users to connect their IoT devices and perform multiple operations, such as data analysis, data storage, and security. In numerous fields, such as urban planning, business, intelligent transportation systems, and traffic optimization, it is crucial to comprehend crowd data. The acquired knowledge could be used to improve traffic patterns, for instance, based on the types of events and local congestion. Such systems facilitate the collection of data regarding congested areas, enabling authorities to monitor and regulate crowds holistically.

Hajj is an example of a heterogeneous massive crowd in which the majority of pilgrims are attending the event for the very first time in their lives. As a result, they are eager to comply with the ritual's requirements regarding its spatial and temporal dimensions. The Ministry of Hajj and Umrah, along with a number of other Saudi government departments and ministries, are responsible for the planning, execution, and supervision of the entire Hajj event. It views it as its responsibility to offer the most superior services available to pilgrims from the moment they arrive in Makkah until the time they depart for their homes in their home countries. The organizers of an event have to contend with a number of logistical challenges. These challenges include the constraints of space and time as well as the diversity of the audience in terms of race and ethnicity, age, language, and culture. Because it is one of the highest priorities of the Saudi government to ensure that the planning and execution of the Hajj goes off without a hitch, the Saudi authorities, the organizers of the pilgrimage, and the researchers are always looking for new methods of crowd management and control. Each year brings with it a slew of fresh challenges and opportunities, both of which are thoroughly investigated, dissected, and improved upon the following year. In the context of Hajj, crowd data analysis can assist with Hajj planning, emergency management, mobile network design, and service development. This study seeks to document the implementation of different tools that have the potential to significantly improve Umrah and Hajj services.

1.1. Related Works. The management of crowds is responsible for many crowd-related issues, especially during massive gatherings such as Hajj. While organizing the movement of a large number of pilgrims to limited ritual sites in Makkah, Saudi Arabia, the authorities of Saudi Arabia face a number of crowd management challenges [4]. Massive crowds cause congestion at focal points, overcrowding, stampedes, injuries, and occasionally death. Foreign pilgrims encounter navigational difficulties and become separated from their groups. Also, pilgrims lose track of crucial locations due to inaccurate information regarding the routes to ritual sites. Consequently, the use of technologies such as IoT can be effective for crowd management [5]. The annual pilgrimage, Hajj, is a Muslim ritual observed once a year in the holy city of Makkah. Recently, there has been a great deal of activity in the management and conduct of this ritual. There are many problems with managing the crowds during Hajj, which creates a number of risks that affect the pilgrims' experience.

The theory of crowd management includes planning and preparation of crowds; assessment of risks and hazards; assistance from relevant authorities; comprehension of crowd behavior; communication and transfer of information between crowds and authorities; use of experienced personnel in the planning of crowd management; and continuous observation and monitoring of crowds. Group behavior is evaluated through the analysis of extracted data to improve crowd management and planning during Hajj [6]. Crowd management employs standardized models for assessing crowd patterns and anticipating the danger they pose to individuals. The models include effective event planning (in this case, Hajj), crowd monitoring and control, and report generation based on feedback. Effective crowd management requires an understanding of crowds and their behavior, which is incorporated into this model. A sudden and violent crowd causes more injuries and deaths. Therefore, all of these problems can be avoided by employing effective crowd management strategies.

Crowd management reduces risks associated with disasters resulting from the mismanagement of crowds by collecting data in real-time using a variety of IoT devices and technologies. It provides robust data analysis using simulations and models for crowd assessment. The risks associated with crowds include stampedes, injuries, casualties, health concerns, terrorism threats, and the collapse of enormous infrastructure. Officials in charge of crowd management try to assess the risk of relieving organizations of financial losses and liabilities and protecting the crowd from any disaster.

There are two perspectives on crowd management: theoretical and practical. The theoretical perspective provides Hajj regulation authorities with step-by-step planning for the execution of crowd management procedures. In contrast, the practical perspective focuses on providing solutions to crowd mismanagement issues, such as Global Positioning System (GPS) and radio-frequency identification (RFID) systems [7]. RFID is an IoT application that monitors and tracks pilgrims using tags and card readers attached to their wrists, hands, and other specific body areas. By tracking the tags, RFID provides users with maps and locations on their mobile phones. Another application of IoT is GPS, which provides pilgrims' mobile phone locations in real time.

Inadequate infrastructure capacity of the event organizer, a large number of pilgrims, and pilgrims' movement patterns all contribute to crowd mismanagement disasters during Hajj. Merging, intersecting, and counterflow in crowded areas pose severe risks and loss threats. The high population density in a confined area during Hajj contributes to the high risk of infectious disease transmission caused by coughs and sneezes, resulting in the emergence of new viruses and bacteria.

In addition, the long-term accumulation of crowds prolongs pilgrims' stays in the searing heat of Arabia, resulting in severe skin diseases. As most pilgrims travel on foot, crowds at important ritual sites contribute to traffic congestion in nearby areas, resulting in disordered traffic conditions. Additionally, there are numerous casualties caused by vehicle accidents on Hajj grounds. Crowd disturbances are imminent in regions depicting intense ritual activities. These include the surging and swaying of crowds, the trampling of individuals, the aggressive behavior of pilgrims, and congestion at exits and entrances. People are crushed between and collide with barriers and structures.

The Internet of Things provides various applications and technologies with a database for crowd management risk assessment in response to the highlighted issues. It creates models for risk assessment prior to the occurrence of massive crowds. Before the annual pilgrimage, the IoT provides an assessment of the event venue, in this case Makkah, using a database collected through monitoring and planning embedded systems. The database stores the total number of attendees and their geographic distribution from prior years [8]. It specifies the anticipated capacity to house the total number of pilgrims. In addition, it enables the management of lines and delays at specific ritual points that contribute to the congestion of vast areas. It also evaluates the behavior of individuals, which significantly defines the intensity of crowds when a violent group attempts to overlap individuals, leading to accidents. IoT sensors and devices permit entry and exit restrictions for pilgrims to address stampede and congestion issues at focal points. IoT systems also offer an effective ticketing system for advance sales and reservations.

The primary objective is to aid Hajj organizing authorities in the development of technologies that assist pilgrims in locating crucial locations during the annual pilgrimage. Several virtual devices use augmented reality to provide pilgrims with real-time assistance. Some devices that incorporate augmented reality to provide realistic simulations include digital compasses, smartphones, mounted and handheld displays, GPS devices, and digital utilization sensors [9]. By pointing devices at the desired location, satellite television uses augmented reality to display the names of places in virtual letters [5]. When pilgrims become lost between important landmarks, augmented reality applications also send them warning messages and direct them to their desired locations.

In addition, augmented reality applications transmit complete, processed data regarding pilgrim movement, gatherings, and activities to the crowd management staff via shared devices and applications [10]. It operates by monitoring location and user data, registering virtual data, and displaying the retrieved information. AR provides virtual maps that allow users to experience realistic simulations of the locations they wish to visit. The applications display the track's path on the screen using virtual lines and arrows. Taileb et al. [9] integrate GPS into augmented reality (AR) applications to improve the location function. It also includes voice signals that provide directions to users. AR enables users to communicate with distant individuals who have difficulty establishing physical contact. The users use the audio channels of augmented reality (AR) applications to communicate in real-time and keep track of their locations, which are displayed on the interface of the AR application. The use of augmented reality applications simplifies and makes more effective and user-friendly crowd management issues. AR applications provide users with information on congested areas and alternative routes to their destinations. These applications reduce the amount of labor necessary to manage crowds at focal points.

Transportation and crowd management have been extensively studied in the past, with various technologies contributing to the management of pilgrim crowds, i.e., during Hajj. In their recent study, for example, Shambour and Gutub [11] have extensively discussed the use of technologies, such as mob apps, wireless, secure mobile computing, and many others, to manage crowds and transportation during Hajj. In a similar vein, Yasein and Alharthi [12] discuss various technological techniques for guiding and tracking Umrah and Hajj pilgrims. In the study, various systems such as RFID/NFC, GPS, scene analysis, land-based tracking systems, Wi-Fi, Hybrid Solutions, and Barcode Systems were compared. These technologies and systems, according to researchers, can significantly assist pilgrims with navigation and route guidance. Similarly, Osman [13] mentioned a technological system for pilgrims' guidance and safety, particularly during the Umrah and Hajj seasons. Researchers proposed using NFC technology to identify and track pilgrims and their family members in densely populated areas. A study was conducted to estimate the overall population density of the Holy Mosque in Makkah using a neural network (NN) algorithm. Alkhuzaim and Altahhan [14] conducted this research with the intention of enhancing the safety and awareness of tourists and pilgrims. It was suggested that the NN model is effective because it has effective classification images and performance, which can significantly aid in projecting the crowd density and classifying videos and images in a crowded environment.

Similarly, researchers such as Jabbari, et al. [15] proposed a framework to address issues such as crowd collision using a mobile device capable of detecting the potential for a collision before it occurs. The foundation of their work was the use of wristbands as identifiers for locater chips and personal data. Similarly, it was considered that bracelets could serve as "Bluetooth" devices for locating and tracking individuals by transmitting signals to the control station and nearby sensors for discovering the pilgrims. According to Kim et al. [16], this analysis of crowd comments is based on Hajj simulations of massive gatherings and right-of-way interactions [17]. According to Aly et al. [18], data collection and dissemination, as well as head collection methods, are crucial for counting pilgrims by distinguishing static images from head regions [19]. In addition, the researchers evaluated the likelihood of an early stampede so that people could be warned and take the necessary precautions. In a similar vein, Khan et al. [20] proposed a framework for improving crowd management during the Hajj season, recognizing that computer vision technology is highly applicable of

automatically analyzing video footage. In order to evaluate and quantify the crowds, the researchers analyzed and compared previously recorded footage. Similarly, the next step involved models employing NN to extract crucial information, such as identifying and discovering congested areas and determining existing patterns of movement and crowd real-time density [17]. Similar to what previous studies have examined, Felemaban, et al. [21] proposed an optimization method to plan the movement of visitors and pilgrims using trains during the Hajj season [22, 23]. Researchers, Felemban et al. [21], identified three factors that influence the scheduling process: the type of train movement; the proximity of camps to train stations; and the location of camps on pilgrimages. During the 2019 Hajj season, it was determined that the recommended method was utilized, and a comparison between the scheduled and actual times at each station was performed.

Other studies in the context of crowd management have focused on crowd congestion; for instance, Seddiq, et al. [24] evaluated crowd congestion using the variable resolution clustering technique. The authors intend to develop an algorithm that can detect crowd movement and assess the severity level of a crowd gathering in three distinct scenarios, including serving congestion, mild congestion, and no congestion, contrary to what has been discovered in the study [25]. The study by Seddiq et al. [24] suggests that demonstrating the usefulness of clustering can aid in assessing the severity of crowd congestion. Researchers such as Amer and Al-Matraf [26] applied MAS (multi-agent system) in an intriguing manner for coordinating negotiations between campaign organizers and the Hajj administration, for instance to evacuate the crowd during the peak period. The projected model MAS is efficient enough to set scheduled times for pilgrims traveling from Arafat to Muzdalifah, and it also includes automated RFID gates for detecting buses that do not adhere to the projected schedule. The researchers [26] also advocated the use of MAS for automating negotiations between travel agents and Hajj authorities in order to make the schedule-setting process more fair and transparent, in addition to the use of automated RFID gates to prevent vehicles without the proper identification card.

Namoun et al. [27] favored the vector machine with the fuzzy logic concept when simulating the movement and behavior of pilgrims in a chaotic situation. The purpose of this paper was to observe a pertinent evaluation model to reduce the likelihood of disasters such as stampedes. The study's findings revealed that the algorithm is useful for selecting the most accurate depiction of pilgrimage crowds because it accurately reflects their movement and behavior. Feleman et al. [28] used an application system for collecting and analyzing pilgrim data and information in time and space domains to explore their movement information, including movement speed, duration time, starting time, and selected path, in order to comprehend the behavior of the crowd during the days of Hajj. Similarly, Islam et al. [3] proposed a machine learning method for detecting crowd congestion during the Hajj. This recommended system collects the necessary data using three bracelet sensors, including an accelerometer, a humidity sensor, and a temperature sensor. Using decision tree algorithms and K-Nearest Neighbors, the collected data are later utilized to predict potential stampedes. Yamin et al. [29] also proposed a framework for crowd management and control to prevent catastrophes and stampedes. The framework's deployment and verification simulation included an algorithm that can accurately predict stampedes. Similarly, Mohammed, et al. [30] proposed a framework for regulating and allocating visitors in a crowded area. The recommended framework consists of three layers, including interface, management, and sensor layers, which are all utilized for data collection, analysis, and the delivery of accurate, timely decisions. The framework is useful for providing users with information about the current conditions of doors and roads, the location of their team members and friends, and areas that are not congested or crowded.

According to Nasser et al. [31], a framework for monitoring and managing crowded areas in Hajj is required. The authors applied smart monitoring of areas in the Al-Jamarat building and Mina's tents as a tool for predicting and detecting congestion. The usefulness of the framework is discussed in comparison to the scheduling mechanisms, such as the weighted round-robin mechanism, priority queuing, and first-in-first-out. Mahmood et al. [32] discussed a crowd evacuation simulation model based on an agent-centric approach. This model is intended for simulating crowd behavior in a spatially realistic environment and evaluating evacuation strategies. According to Nasser et al., the game theory approach is similarly crucial for the management of crowds during the Hajj [33]. In addition, the primary objective of Nasser et al.'s study was to prevent pilgrimage bottlenecks during the stoning phase at the Jamarat building. In order to investigate the crowd dynamics during the Hajj, Mnsari and Farhat [34] also presented various suggestions for enhancing crowd movement. Similarly, Alazbah and Zafar [35] utilized a convolutional NN algorithm to detect congestion during the Jamarat building stoning ritual. The algorithm was developed using various classified images extracted from raw footage of pilgrims traversing the Jamarat route. The aforementioned algorithm classified the crowd's condition into three categories: normal, semi-congested, and crowded.

Felemban et al. [21] examined bus traffic during the Hajj season. In the study by Jabbari et al. [36], a bluetooth-based intelligence crowd system (ICS) was described that can help prevent disasters during the Hajj. The suggested ICS can aid in elucidating crowd characteristics such as density, velocity, location, and direction. In other research [5, 37–40], similar networks are also mentioned.

In contrast, Felemban et al. [5] stated that spatial computing is the field associated with the management of crowds during the Hajj, when pilgrims move from one location to another for the spatiotemporal rituals of Hajj. Prior to the main Hajj event, it involves the scheduling of pilgrims at the holy sites, including Jamarat, Muzdalifah, Mina, and Arafat. In a similar vein, Haase et al. [41] propose a crowd management decision support system based on operational research. The proposed system provided a

scheduling tool and real-time video tracking (VBCS) to ensure a smooth and uncongested flow of the crowd, as well as real-time statistics for an early warning system. It was determined that the system was effective in reducing fatalities because no major disasters were reported between 2007 and 2014.

In the study by Kantarci et al. [42], it was mentioned that Saudi Arabia's Ministry of Hajj and Umrah collaborated with Saudi Arabia's Ministry of Hajj and Umrah to design and implement a dashboard to monitor the progress of pilgrims as they walk through various holy sites during the 2020 Hajj. Felemban et al. [28] stated that Al-mutawf and Al-Harmain are the apps launched by Saudi authorities to display the status of the crowds in the Two Holy Mosques, Madinah and Makkah. The Al-Harmain app provides video, live audio, contact us, frequently asked questions, navigation, prayer times, supplication, and Umrah ritual instructions in Urdu, English, and Arabic. The app also assists users in requesting itikaaf, Kiswa permission, and a wheelchair. It also provides a type of contract for any requests, suggestions, or complaints made by pilgrims during their stay at holy sites. According to Owaidah et al. [43] and Owaidah [44], AR (augmented reality) is also useful in assisting Hajj organizers in managing the mobility of pilgrims and providing them with directions if they become lost. In a similar vein, Islam et al. [3] described how PDAs (personal digital assistants), smartphones, handheld displays, GPS, cameras, and digital compasses can aid in guiding pilgrims and even managing crowd movement. Similarly, AR techniques are useful for assisting pilgrims in locating their camps and points of interest at holy sites.

1.2. Different Technologies Are Applied in the Hajj and Umrah Systems. Researchers have witnessed significant and clear advancements in the Internet of Things (IoT) field and the concept of technologies in a variety of human endeavors in this modern era. These changes have occurred as the world has gone through significant transformations in this modern era. At present, the idea of technological applications is being referred to as the fundamental component of countries' and peoples' progress toward prosperity and development in terms of a variety of services [2]. The most basic illustration relates to doctors, who depend on technological equipment to investigate diseases and assist in accurately assessing the type of illness a patient is suffering from. Researchers have also determined that numerous other technological applications have had an impact on commercial and industrial organizations that aim to reduce the amount of time they spend doing activities and increase the amount of activities they do [5]. In today's world, technology also plays an important and dynamic role in the realm of education. The implementation of the Internet of things technology has significantly addressed all of the requirements of communities as well as the requirements of individuals. These requirements include detection systems, entertainment services, media, data conversations, and smart cities, regardless of whether they are provided in a school or an education center.

It is clear that the Umrah and Hajj crowd management systems in Madinah and Makkah are becoming increasingly reliant on technologies related to the Internet of Things (IoT) and the applications of these technologies. In addition, the Internet of Things has been critically important in the functioning of the two holy mosques, as well as galleries, museums, libraries, and sacred sites [5]. The pilgrimage known as Hajj is considered to be one of the five pillars of Islam as well as the most important act that all Muslims are required to carry out at least once in their lifetime. Pilgrims are obligated to imitate Prophet Muhammad in all aspects of their behavior while performing the Hajj (peace be upon him). This idea helps to further solidify the link that exists between hajjis and the teachings of the prophet [3]. In order to achieve a seamless integration of all hajj procedures and to successfully carry out the multiple operations, it is necessary to implement other technologies in addition to the Internet of Things. In addition, technology makes it easier to safeguard data and store it, as well as to create dashboards. The comparison of Umrah and Hajj reveals that there are four primary branches that need professional and specific attention for integration; these four branches are as follows: Umrah, which refers to the circumambulation of the Kaaba in Mecca; Hajj, which refers to the pilgrimage.

(i) The holy sites as well as mosques
(ii) Pre-arrival logistics
(iii) Service studies and host organization
(iv) Organizing the movement of people and transportation

Pilgrims make use of smart communications devices and mobile phones throughout the Hajj in order to connect to the various services that are offered and generate massive amounts of data. The Internet of Things (IoT) provides a foundation for analyzing copious amounts of data in a centralized location. The Internet of Things, also known as IoT, is one of the developing technological fields that has emerged in the modern era. As a consequence of this, it was possible to find solutions to a great number of scientific, medical, and technological problems [11]. The Internet of Things (IoT) includes technologies such as radio-frequency identification (RFID), which is one of the technologies used for managing crowds.

Immersive Internet of Things technologies, such as augmented reality (AR), offer a view of the real world in real time that is augmented with computer-generated virtual information. Emerging technologies such as the artificial intelligence, Internet of Things (IoT) and data science, amongst others, are utilized to collaborate, automate, and facilitate the completion of human tasks, which results in a simplification of the work that needs to be done by humans. Yamin's [45] survey evaluation and background research reveals that a variety of currently available technologies are being used, such as machine learning algorithms for wireless sensors that aid in effecting networks and aid in drawing parameters for the linkage of every aspect using large-scale GPS. Another example of a current technology that is being used is the blockchain, which is a distributed ledger that can

be used to store and transfer value. Information regarding tens of thousands of buses and other forms of transportation was collected, analyzed, and visualized with the assistance of a cutting-edge interactive platform. In addition, the algorithm that was analyzed in the study can be used to limit the number of people who cross paths during an evacuation by preventing spatial anomalies. This can be done by limiting the cross-movement of people. Algahghi [46] came up with a similar idea and proposed a flow simulation model for Hajj passengers traveling through King Abdulaziz International Airport. The waiting time for passengers was investigated using a variety of simulation strategies, and the results indicated that the flow of passengers can be improved by improving the process of policies rather than increasing the resources. This was determined by the fact that the flow of passengers could be improved without increasing the resources. In a similar vein, Yamin, et al. [29] discussed the significance of mobile and wireless technology for the management of crowds. They argue that radio-frequency identification, or RFID, is useful for a variety of applications, including crowd control and monitoring; the use of fog computing devices to reduce the cost of cloud-based communication and processing; and more.

2. Current Technologies

The following are some other current technologies being used in Hajj and Ummrah.

2.1. Mobile Augmented Reality. According to Olsson et al. [47], digital phones, such as smartphones, cameras, and explorers, are becoming project sponsors and a contributing element in the deployment of augmented reality technology [47]. On these mobile devices, social networking sites, gadget orientations, and virtually every other setting have become information sources (e.g., images, videos, and audio). Furthermore, according to Jang and Hudson-Smith [48], the emergence of devices equipped with a GPS receiver, a computerized compass, and inertial sensors has hastened the usage of geographic information in emerging mobile apps. This extensive variety of sensors has enabled the development of interactive digital applications for a variety of devices. AR has been implemented on smartphones as a revolutionary technique in a range of industries, such as entertainment, retail, and social networking sites. In addition, these mobile devices enable users to identify their location and the quantity of information presented on multiple computer monitors. In their study, Yagol et al. [49] highlighted the effect of connecting augmented reality and portable technologies only to a global positioning system in the context of apps that may be used outside the home. Behind structures, spacecraft transmissions are hampered or incorrect, and GPS equipment requires access to natural light [50]. In addition, they demonstrated the significant capabilities of using GPS technologies in augmented reality technology to determine the basic configuration by determining the location, GPS tracking of the process of traveling from one location to another, and the ability to detect changes in government action.

2.2. Spatial Computing. When pilgrims move from one location to another to perform the ritual of Hajj, one of the current technologies that helps with the management of the crowd has been the concept of spatial computing, which has been among the other technologies that are currently available. This takes place as pilgrims make their way from one location to another in order to perform the Hajj. As it did before the Hajj, it intends to deal directly with the scheduling of pilgrim movement within holy sites [51]. The authorities of the organization make every effort to ensure that the pilgrims are adhering to the planned itinerary, and the application also makes a request in advance to reschedule the activities in the event that something unexpected takes place. In addition, the authorities make every effort to ensure that the pilgrims are adhering to the planned itinerary.

2.3. Crowd Modelling and Simulation. The idea of crowd modeling and simulation is usually done before Hajj starts as it helps in understanding human behavior from past years. This was formed by Professor Keith when he was involved with the Ministry of Umrah and Hajj from 2000 to 2005 [51].

2.4. Smart Screen Devices. One of the most recent innovations is the use of smart screen gadgets, which are used by the system to eliminate the danger of Umrah performers and pilgrims being separated from one another. The idea of distributing screen gadgets in a certain position in each of the two holy cities is to aid tourists in the event that they become bewildered [51]. The technology on the item works similarly to a bracelet. The person who has gone missing must wear the bracelet with NFC technology in order for the gadget to aid in tracing a route from their present location to their preferred one.

2.5. Monitoring System for Abnormal Events. A wide variety of surveillance cameras are used to keep an eye on unusual occurrences. As a direct result of this, these cameras have been installed in two holy mosques so that holy sites can carry out their rituals in an atmosphere of increased safety [52]. The cameras contribute to the monitoring of all kinds of events and provide excellent follow-up, with a particular emphasis on locating any activity or occurrence that is not relevant but could lead to a problem.

2.6. Smart Parking System. A smart parking system is an interactive device at the main exit that leads to large parking lots, especially in Madinah. Recently, this technology has been developed. The technology helps figure out where a car is parked based on the number on its license plate [52]. The device works by showing a picture of a car on its screen and pointing the person using it in the direction of where they parked their car.

3. Future Technologies

3.1. Big Data and Artificial Intelligence Technologies. Big data and the Internet of Things (IoT) are attractive study subjects

in the Hajj and Umrah systems because they may be utilized to enhance data-based decision-making in a variety of disciplines [5]. Numerous academics [28, 52–54] have created a range of frameworks for maximizing the utilization of massive amounts of data. In view of reliability and security issues, however, additional studies must be undertaken on the benefits of big data and the Internet of Things (IoT).

3.2. Augmented Reality and Hajj. Augmented reality (AR) is a real-time view, either indirect or direct, of the physical world that incorporates data generated by a computer. It is able to assist Hajj organizers in regulating the mobility of pilgrims and providing directions to lost pilgrims as well as sites [5]. Taileb et al. showed off a mobile phone app that uses GPS, a compass, and an accelerometer to show pilgrims images and descriptions of important places in real time.

4. Discussion

There are several issues related to the crowd management of Hajj, and most of the issues are related to organizational operations, the high ratio of people, and lack of guidance and information. These issues would lead to the loss of tourists during Hajj programs. As a result, effective machine learning and artificial intelligence with digital phones could be a useful tool for Hajj officials, including workers, in a variety of ways. Due to the paucity of instructional supervision at Hajj, Hajj officials could have used Mobile Augmented Reality (MAR) to obtain intelligence for visitors and assist them in reuniting with their unit. Such directions might be given to them instead of instructing individuals and informing the person in charge. Furthermore, these travelers might be directed to utilize a variety of media, including voice, writing, and television [55]. Furthermore, according to Taileb et al. [9], MAR may assist Hajj workers in facilitating Hajj organizational procedures for visitors. For instance, it provides all the necessary data about the Hajj system's boundaries. For instance, by situating the image of MAR gadgets, including phones or tablets, Hajj employees may discover and identify geo-located sites (POIs of Hajj). Furthermore, Al-Salehi et al. [56] also discussed that MAR systems might be employed as video recording detectors and linked to a centralized power center for Hajj monitoring systems. As a result, such services are regarded as conduits between Hajj administrators on the platform and Hajj personnel on the ground. Due to how well MAR works for Hajj staff to talk to each other and share information, the controller is always keeping an eye on the Hajj sites and collecting a wide range of information collected by Hajj staff.

Augmented reality is selected due to its simulation capacity of the real world to the virtual world, which provides a deep understanding of complex situations such as crowd management in Hajj. MAR utilizes electronic medium elements and characteristics like television, voice, and writing rarely found in previous researchers' works cited. The results indicate the practical usage of MAR in providing geographical locations through the virtual usage of gadgets, phones, and smartwatches. The findings signify that the detectors of MAR are capable of recording videos of the pilgrims about the location they currently assume and providing them with the centralized system of Hajj [29]. The videos provide constant surveillance of the interaction of the pilgrims with POI during Hajj.

Another method, Mora et al. [57], uses augmented reality in mobile phones and electronic gadgets due to its numerous benefits and advantages over traditional uses of technology in regulating and controlling large gatherings. The results indicate the immense reliability of using mobile phones to apply augmented reality due to easy outdoor usage, portability, and smooth integration of complex technologies such as augmented reality. Mobile phones also provide a decent combination of high speeds with efficient data exchanges due to the supportability and compatibility of phones with high-speed Wi-Fi, 4G, and 5G networks. The results also endorse the compatible integration of AR components with mobile phones, such as sensors, cameras, and GPS, gyro sensors, and accelerometers [57].

Previous research found it difficult to track and register a considerable number of people in a crowd, especially in enormous annual gatherings like Hajj. The application of augmented reality on mobile phones addresses the issues most effectively by tracking pilgrims in essential places and sharing virtual data with the Hajj regulation systems. The successful integration of AR in mobiles is due to the high-resolution display power of mobiles. Mobiles have a built-in camera and GPS features that provide a live recording and scenario-capturing facility, which helps integrate surroundings with the user's mobile and allows captivating evaluation of the live environment [29]. Mobile phones also allow straightforward graphical augmentation of reality with an overlay of live streams before displaying events. Developers and programmers easily integrate mobile phones with augmented reality technology due to their lower power consumption, the relatively high computational power of mobile phones, video, audio, and capturing features, efficient storage, and compatible technical capacities. The results of the adopted technology in mobiles endorse and certify the feature of mobile AR to interact with AR components on a single communicating device using an Internet browser. The mobile device allows changes in data on the server without using an external device.

While assessing previous research for the features that safety and security systems consist of, the proposed technology is designed around the abilities of tracking, data retrieval, registration of virtual data in association with real-world data, and accurate display of virtual data on the natural ground using 3D graphics. Mobile augmented reality has been previously tested in applications relating to shopping malls, data network sites, restaurants, etc., which provides a basis for testing it in crowd management. The results are based on existing shreds of evidence and support the customer design of augmented reality in mobile applications, as highlighted by Billinghurst [58] and Langlotz and Schmalstieg [59], with minor changes and innovations in the generic framework. To solve crowd management issues in Hajj, the suggested framework of the paper proposes a Monitoring and Management Advance Computer

(CMMAR) program for the mobile augmented reality application that allows observance and inference of the crowd by the Hajj officials. Numerous frameworks are studied before selecting CMMAR as it provides rapid data to the officials. The framework provides for the regular evaluation of crowd movement and flows with the robust distribution of relevant data to the relevant staff in case of any discrepancy. The framework allows introspection of the Hajj control panel.

Developing mobile augmented reality applications is a tedious task that faces several limitations that need corrections for future studies. Numerous ethical concerns revolve around MAR regarding the use of global positioning systems [60]. The GPS assesses the live location and details of the user and the person being observed and poses threats to the person's privacy. Therefore, it is recommended to develop applications that protect the users' privacy by employing strict security measures while assessing the GPS. It is noted that GPS satellites are owned and governed by governments that get all the databases of the MAR systems [54]. GPS systems fail to work in adverse weather situations. Therefore, it is recommended to develop positioning systems unaffected by unfavorable situations and should be regulated by centralized authorities to provide complete privacy and security to the people. The algorithms related to AR are complex and need professional developers and programmers to integrate them into mobile phones. The augmented screens fail to capture essential features from the user's end due to technical limitations in the interaction between the mobile phone and the user environment [2].

Currently, spatial computing, crowd modeling simulations, smart screen devices, crowd monitoring and risk assessment systems, intelligent parking systems, cluster systems, and intelligent building technologies are used in an attempt to minimize crowd management issues by providing specific schedules, simulation of human behavior of crowds through past data, screens in essential locations to find lost pilgrims, surveillance cameras recording unusual activities, and innovative parking facilities to avoid congestion [53]. Furthermore, it is recommended to develop data and artificial intelligence technologies for crowd management that cater to numerous concerns in a single framework. Of the emerging technologies, it is also recommended to develop and implement immersive technologies to provide virtual-world simulation features of the natural world and allow tracking of crowd mobility. The study needs surveys and questionnaires to take the view of Hajj management teams in developing an understanding regarding the use of advanced immersive technologies to obtain feedback on their user experience of the developed applications, and this provides domains of improvement in the technology as the technology is itself in the growing phase. Therefore, these limitations need to be addressed for the future development of these technologies.

5. Conclusion

Managing the gathering of millions of pilgrims from around the globe in Makkah for the Hajj is a daunting task. Diverse in language, age, race, and culture, the Hajj crowd necessitates an adaptable set of services for optimal Hajj ritual performance. Efforts are being made to ensure the smooth organization of the Hajj and to permit researchers to explore modern methods and implement the most advanced technological techniques in order to improve the quality of services offered. In this paper, we examine the advanced technologies that have been used for crowd management during previous Hajj events, as well as the solutions that have been implemented to improve the safety and security of pilgrims during their stay in Saudi Arabia. This paper offers an examination of different technologies. This paper's findings suggest new research avenues and a more realistic and pragmatic strategy for enhancing services during Umrah and Hajj.

Data Availability

The datasets used to support the finding of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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