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Proposed Methodology for Using Internet of Cultural Things (IoCT) in Conservation on Cultural Heritage Sites

Aml Abd El-Wareth Mohamed [a]*

[a] *Faculty of Fine Arts; Assiut University, Egypt; Director of Assurance Quality, Faculty of Fine Arts, Assiut University, Egypt*

Abstract

New and interactive technologies Technology, especially the Internet of Cultural Things (IoCT), plays an important role in conserving cultural heritage as a powerful tool that connects, through the Internet, people to their vast cultural resources. A research problem appears in the lack of sufficient use of the capabilities of the Internet of Things (IoT) to achieve interaction with cultural heritage sites. This research aims to develop a methodology for the effective use of (IoT) and smart technologies in enhancing participation, interaction, and conservation on cultural heritage sites. The research prioritizes the selection of appropriate (IoT) technologies, services, principles, and applications. The research follows a theoretical, descriptive, and analytical approach, consisting of four main parts. These sections cover IoT and IoCT, and their relationship with cultural heritage, a case study of the Church of the Holy Archangels Michael and Gabriel in Sarajevo, Bosnia and Herzegovina, and a proposed methodology for benefit of IoCT in conservation on cultural heritage sites. The research focuses on the potential of IoCT in reviving cultural heritage, especially heritage buildings and sites. It is recommended to adopt the best IoCT technologies, services, and applications supported by data science and analysis techniques effectively for conservation on cultural heritage sites.

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KEYWORDS: Internet of Cultural Things (IOCT); Smart Environments; Cultural Heritage sites; Cloud Computing.

1. INTRODUCTION

In the early 2000s, many multimedia systems explored the use of (IoT) models in cultural heritage sites what is known as (IoCT). These efforts aimed to design innovative systems that support visitors in cultural heritage sites, and enhance smart building designs through advanced sensors and services[1]. (IoT) connects cultural heritage sites to become part of an interconnected network with devices and sensors. This done by passing data through (Gatways) to analyze and store it in the (IoT) cloud, then display it in a form (User interface) that facilitates its use. Since 2010, some countries such as the United States, China, Korea, and Japan funding (IoT) research. Hence, Arab countries, like Egypt, should explore IoCT's potential for cultural heritage conservation and advanced information services at heritage sites[1].

1.1. Research problem

Research problem becomes apparent in the current inability to benefit from the application of new trend (IoT) and the capabilities of smart environments and systems by using (IoCT) in achieving interactivity within heritage buildings, areas, and conservation on cultural heritage sites.

1.2. Research Aim

This research aims to study the development of a proposed methodology for the possibility of benefiting from one of the technological applications and modern architectural trends such as (IoT) in conservation on cultural and civilizational heritage sites

* Corresponding author: aml.a.m@farts.aun.edu.eg

1.3. Research hypothesis

The research assumes that using (IoCT) increases the effectiveness of linking various devices and applications through the Internet and computing to cultural heritage sites and enables their conservation and sustainability for future generations.

1.4. Research Methodology

The research paper follows the theoretical descriptive analytical approach. It is divided into four main parts, First: includes a theoretical background on the concept of the Internet of Things (IoT) and the Internet of Cultural Things (IoCT) and their components, Second: deals with the relationship between conservation on Cultural Heritage and (IoCT) computing by studying the concept of cultural heritage, its types and importance of (IoCT) in Conservation on Heritage, its principles, challenges, technologies, and fields of (IoCT) Applications , Third: a case study of the possibility of benefiting from the (IoCT) in conservation on cultural heritage building a church (The Church of the Holy Archangels Michael and Gabriel) Sarajevo - Bosnia and Herzegovina, Fourth: A proposed methodology to benefit from the (IoCT) in conservation on cultural heritage, and the research paper ends with results and disscion then a presentation of the most important conclusions, which can be summarized in that the smart use of the (IoCT) can breathe new life into cultural heritage, especially heritage buildings, and sites. The study recommends adopting the best technologies, services, applications of (IoT) to conservation on cultural heritage sites, by properly evaluating the collection of (IoT) data in the field of cultural heritage through techniques of data science and analysis and using proposed methodology in the research.

2. A THEORETICAL BACKGROUND ON THE INTERNET OF THINGS (IOT)

From computing to mobile devices and now the "Internet of Things" (IoT) age[2], technology has evolved significantly. Age of (IoT) emphasizes smart environments, energy-efficient networks for sensors and devices, and mobile applications, enabling user mobility for accessing cultural heritage sites. This research explores applying (IoT) for conservation on heritage sites.

2.1. Concept of Internet of Things (IoT)

(IoT), the next- generation Internet, facilitates device communication via Internet Protocol, connecting physical devices to form a virtual network [2], [3]. It's a complex, comprehensive system requiring careful planning, user-friendly interfaces, and compatibility. (IoT)'s goal is to store data without human involvement, linking cultural heritage sites to the digital world [4]. **These things are divided into two types:**

1. **Physical things,** in the real world, like robots, smart devices, and sensors, interact with and respond to their surroundings by collecting, transmitting, and acting on data.
2. **Virtual things,** that exist in the world of information and can be stored, processed, and accessed. Such as multimedia content and application software.

2.2. Components of (IoT)

(IoT) involves interconnected networks, devices, and data across long distances. A complete IoT system comprises four key components: sensors, Internet connectivity, data processing software, and a user interface [5], as Fig. 1.

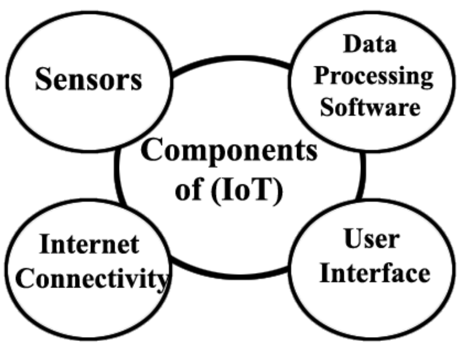

Fig. 1. (IoT) Devices, Source: Researcher.

2.2.1 Sensors devices

Sensors are the first layer of the (IoT) ecosystem, essential for collecting accurate and reliable data. They consist of sensors and actuators.

A- Sensors / Probes

Sensors, also known as “detectors”, collect precise real-time data from the surrounding environment, measuring various factors like temperature, humidity, light, (UV), and gas. They help safeguard heritage assets by rapidly detecting potential damage through data sent to server platforms [6], Fig. 2.

B- Motors/ Actuators

Actuators respond to signals or commands by taking actions. For instance, they can control heating and cooling, like a smart air conditioner that stops when sensors detect no one in the room, as shown in Fig. 3.

2.2.2 Communication

Communication is a vital component of (IoT), facilitating network connectivity between devices, sensors, actuators, and the cloud. This communication enables data decoding and subsequent actions within the (IoT) network.

A- (IoT) Protocols

Data collected by sensors needs a secure communication channel to reach the cloud. (IoT) protocols establish this connection, allowing secure communication between devices, and forming an invisible language for physical objects to interact. Various IoT protocols are available for this purpose. Fig. 4 shows the types of (IoT) protocols.

Fig. 2. Sensors/ Probes[7]

Fig. 3. Motors/ Actuators[8]

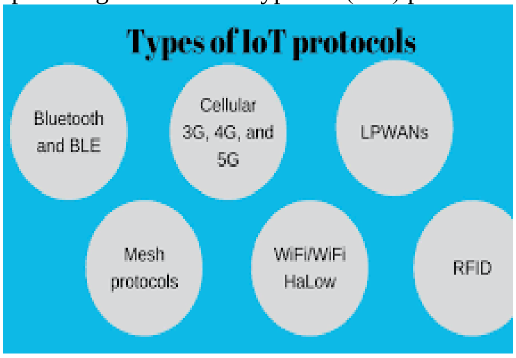

Fig. 4. (IoT) Protocols[9]

B- (IoT) Gateways

The raw data from the sensors must pass through the gateways to reach the cloud. So, Gateways play a crucial role in (IoT), translating network protocols for seamless communication between devices and ensuring data traffic management and security. They act as a protective security layer, using advanced encryption technology to safeguard data from unauthorized access and malicious attacks, Fig. 5.

C- (IoT) Cloud

The cloud processes collected (IoT) data swiftly, connecting all components and making real-time decisions. Speed is vital, especially for critical situations like health and safety, where response time cannot be compromised. (IoT)'s main aim is to provide real-time information, making it an agile, secure framework for connecting sites, people, and applications, Fig. 6.

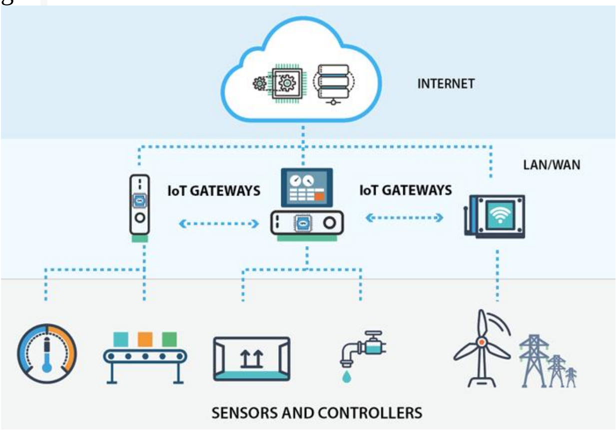

Fig. 5. (IoT) Gateways [10].

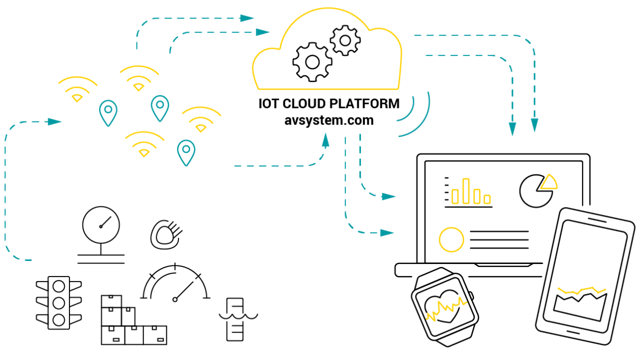

Fig. 6. (IoT) Cloud[11].

2.2.3 A Program for Data processing and Analysis

(IoT) analytics processes extensive data, identifying key performance indicators (KPIs) and anomalies in real-time, enabling immediate action to prevent issues. It's valuable for data management and decision-making across various scenarios, like monitoring room temperature for acceptable ranges.

2.2.4 User interface

(IoT)'s user interface enables device control and preferences, accessible via devices or remotely using smartphones and other devices[12]. Technologies like Wireless Sensor Networks (WSN), (BLE), Near Field Communication (NFC), and Radio Frequency Identification (RFID) enhance museums for inventory management and interactive visitor experiences. Advances in Information and Communication Technology (ICT), (Wi-Fi), mobile devices, sensors, and cost-effective applications are transforming operations and services. Various communication options are offered by Low-Power Wide Area Network (LPWAN), Wireless Local Area Network (WLAN), and Wireless Personal Area Network (WPAN) technologies.

2.3. Concept of the Internet of Cultural Things (IoCT)

(IoCT), the fusion of (IoT) with cultural heritage, integrates objects of cultural and historical significance into the digital world. This extension of (IoT) enables digital access to cultural assets, enhancing innovative approaches to conservation, exploration, and interaction. (IoCT) explores the application of (IoT) in conservation on cultural heritage, introducing new remote access possibilities through museums and virtual heritage sites, revolutionizing traditional conservation methods.

(IoCT) integrates cultural artifacts, heritage sites, and conservation into practices the digital world via interconnected devices, data analytics, and Artificial Intelligence (AI), enhancing global cultural understanding[13], Fig. 7. It transforms cultural sites into "smart" environments, linking (IoT) sensor technologies with the surroundings.

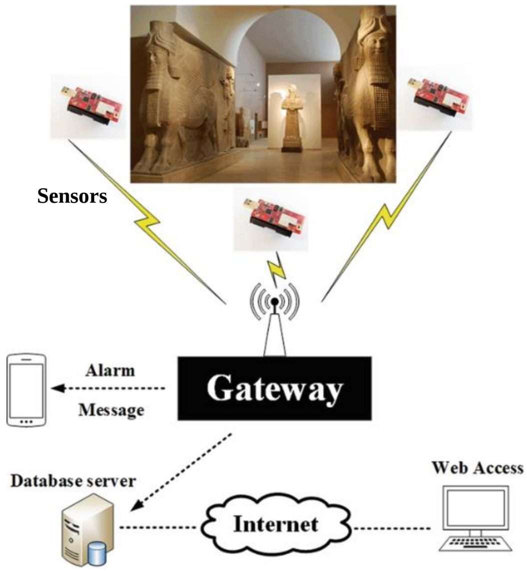

Fig. 7. (IoCT) linking (IoT) sensor technologies with cultural sites transform them into "smart" environments [12].

2.4. History of the Internet of Cultural Things (IoCT)

The Internet of Cultural Things (IoCT) dates back to the early 2000s with the advancement of technology and the widespread availability of the Internet. (IoCT) has transformed traditional museum experiences and other heritage sites into experiences that enhance the exchange of knowledge and appreciation of diverse cultures around the world[13].

2.5. Steps/ Mechanisms of Internet of Cultural Things

First step: Data collection: Sensors collect data, sending it to the cloud via various connections like smartphones, satellites, (Wi-Fi), and Bluetooth. Data is transmitted across the network through (IoT) gateways or other communication devices [14].

Second step: Analyzing the information: Data analysis occurs autonomously, but user intervention is possible for device adjustments or data access. The complexity of data processing depends on the data's nature and volume. The results are conveyed to users as alerts, enabling sensor setting modifications, and sometimes automatic adjustments.

3. RELATIONSHIP BETWEEN CONSERVATION ON CULTURAL HERITAGE AND (IOCT) COMPUTING

(IoCT)'s connection to conservation on cultural heritage is intricate but promising. It harnesses (IoT)'s sensor and smart technologies to enhance user experiences, sustainability, and knowledge transfer within cultural heritage sites, making it a valuable application in this field [15].

The tremendous development and amazing uses of information and communication technology (ICT) and smart applications have enabled new ways of human informational communication with cultural heritage to access and deal cultural heritage information intertwined with devices [16].

3.1. Concept of Cultural Heritage

Cultural heritage, reflecting the achievements of civilizations, encompasses tangible and intangible assets like monuments, art, landscapes, traditions, and languages. UNESCO defines it as: “the inheritance of tangible and intangible legacies from previous generations, which must be preserved for future generations”.

3.2. Types of Cultural Heritage

The types of cultural heritage that deserve to be protected and preserved optimally for future generations are divided into two types [14]:

(1) Tangible Cultural Heritage: either movable as artifacts, or immovable as urban and architectural heritage, memorials, historical scenes, cultural landscapes, monuments, historical buildings, and archaeological sites.

(2) Intangible Cultural Heritage: It includes traditional skills and crafts, traditional arts, oral traditions, artistic expressions, performance arts, social practices or rituals, and various traditions and languages. Hence, cultural heritage is an important factor in preserving cultural diversity in the face of growing cultural globalization [17].

3.3. Importance of (IoCT) in Conservation on Heritage

(IoCT) empowers devices with data transmission, analysis, and decision-making capabilities, enhancing connectivity and cultural heritage management[18]. It creates an interconnected ecosystem for enriched cultural experiences and resource management[19]. (IoT) applications monitor heritage environments, such as humidity and structural conditions, via online sensors, fostering data integration, management, and analysis across cultural institutions and research organizations[20], Fig. 8.

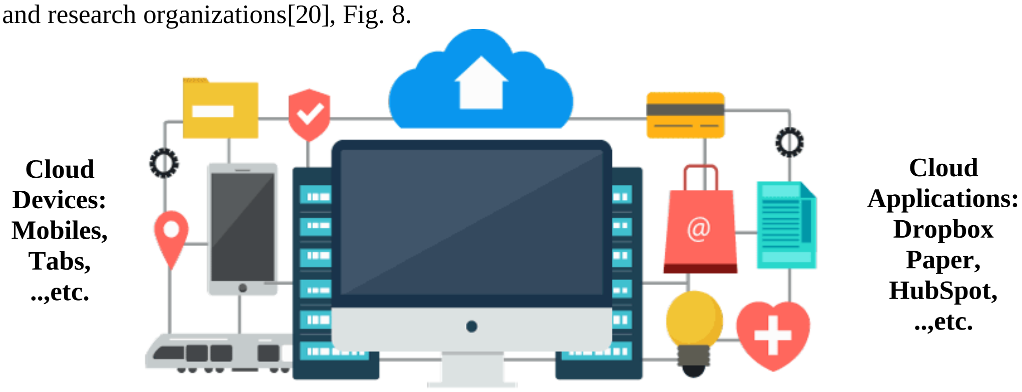

Fig. 8. Various (IoCT) devices and applications and their connection to cloud computing [12].

(IoT) can modernize traditional sites into informative, digital, and smart sites while enhancing heritage conservation efforts[21]. Modern IoCT technologies offer accuracy and advanced tools for asset reconstruction, simplifying documentation, analysis, conservation, and presentation [22]. Successful IoT systems depend on effective integration of devices, sensors, and data management [23]. (IoCT) connects physical objects, artworks, and artifacts to the Internet, providing rich context and spatially unconstrained access to cultural items. It enables real-time monitoring and conservation, safeguarding delicate artworks from environmental damage.

3.4. Principles of (IoCT) for Conservation on Cultural Heritage

The basic principle of (IoCT) is to benefit the power of the Internet and computing to preserve, document, and enhance cultural heritage artifacts and sites, by combining the physical and digital domains as follows:

1. Data Privacy and Security; Possibility of creating comprehensive databases with priority given to protecting sensitive data related to cultural heritage, visitor interactions, and location information. Implementing strong security measures to control data access, preventing malicious use, and ensuring privacy.
2. Promote Sustainability; Through a sustainable plan to maintain and conserve, share, and experience various cultural heritage sites in innovative ways in the digital field without compromising the authenticity or integrity of heritage sites.
3. Integration and Flexibility; They're key in (IoCT) systems, combining advanced technologies like sensors, Artificial Intelligence (AI), data analytics, and cloud computing to support cultural heritage conservation, exploration, and adaptation to evolving conservation methods.
4. Application: By equipping heritage sites with sensors, they can be monitored in real-time to detect any environmental changes or potential risks. This allows proactive measures, such as adjusting temperature and humidity levels, to ensure the long-term conservation on valuable cultural objects.
5. Promote the Exploration of Cultural Heritage; Through AI-driven data analytics facilitates dynamic data collection, processing, and analysis. This enhances understanding across historical, touristic, economic, and traditional dimensions, aiding heritage conservation efforts for researchers and professionals.
6. (IoCT) enables personalized, interactive museum experiences via augmented reality and website services, enhancing deeper cultural appreciation and understanding through dynamic interfaces[24].

3.5. Challenges of Using (IoCT) in Conservation on Cultural Heritage

There are many challenges when integrating (IoCT) technologies in conservation on historical buildings:

1. Integrating (IoT) into heritage sites can pose challenges due to compatibility with outdated infrastructure and potential harm to historical authenticity. Sensitivity to physical changes is crucial when installing (IoT) devices in heritage buildings [25].
2. The management and analysis of huge amounts of data generated by (IoT) devices. in a manner that informs well-known traditional conservation methods.
3. Security is vital for safeguarding cultural heritage sites and valuable artifacts connected to (IoT) networks, requiring a delicate balance between technological advancements, and preserving historical value.

3.6. (IoCT) Technologies

(IoCT) encompasses a set of interconnected practices and technologies that connect the physical and digital worlds, enabling the integration of artifacts, architectural spaces, and activities within cultural heritage sites. The main technologies are:

1. Collecting and analyzing data through sensors embedded in cultural objects or environments. These sensors can provide valuable information on factors such as temperature, humidity, light levels, and visitor movement patterns[26].
2. Technologies allow image recognition and the identification and classification of artworks or historical artifacts using extensive databases[27].
3. Location-based services that use signals or Global Positioning System (GPS) to provide real-time information about cultural sites or exhibits to visitors' mobile devices[28].

3.7. Fields of (IoCT) Application Conservation on Cultural Heritage

1. Benefiting of interconnected devices, sensors, and data analytics to digitize and protect historical artifacts, traditions, and practices for future generations.
2. (IoCT) enables interactive exhibitions using wearable devices, enhancing cultural exploration and appreciation through augmented and virtual reality experiences at museums and heritage sites.

3. Cultural research and education leverage digital integration to access vast data, enabling deep analysis, benefiting academic disciplines like archaeology and history. (IoCT) facilitates immersive learning through virtual cultural interactions.
4. Wireless sensor networks enable remote monitoring and management for environmental conditions, structural changes in buildings, and abnormal events in heritage sites[29].
5. Cultural sites, exhibition environments, and museums can become part of a network of interconnected entities, thus transforming traditional spaces into smart ones, and moving to the concept of a smart environment by using new multimedia technologies to design new approaches to understanding heritage. As shown in Fig. 9.

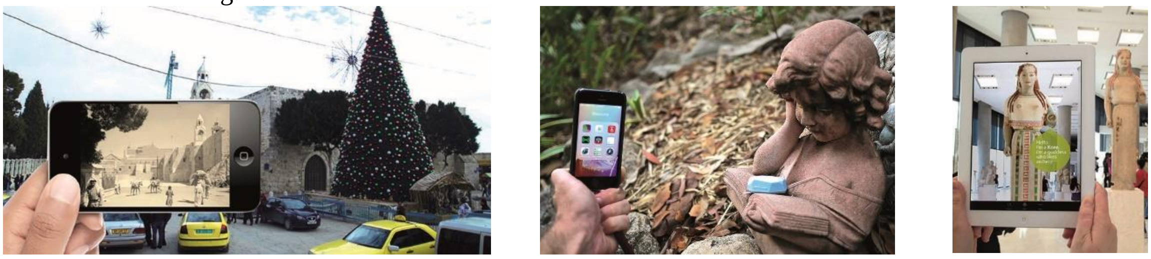

Fig. 9. Italy's "Maschio Angioino" Castle has evolved into a smart museum with an IoT-based model featuring sensors and services. This innovation enhances the user experience, allowing access to cultural content via smartphones and wearable devices[21], [30].

3.8. Strategies of the (IoCT) in Conservation on Cultural Heritage.

Here are some strategies for using (IoT) in conservation on cultural heritage:

1- **Smart sensors for environmental monitoring:** These include monitoring environmental conditions such as temperature, humidity, light exposure, and air quality. This data helps restoration officials identify potential risks to artifacts and building structures, enabling timely interventions to prevent deterioration.

2- **Monitoring and remote control:** (IoCT) allows monitoring and remote control especially when conservation on remote or fragile heritage site environments where physical presence is limited.

3- **Data-based decision making:** Collect and analyze data from (IoT) sensors to make conservation decisions. This data-based approach helps preservers understand how environmental factors affect artifacts and cultural heritage sites, leading to better conservation strategies [31].

4- **Preventive maintenance:** by using (IoT) devices to monitor the safety of construction buildings, monuments, or heritage sites. This helps identify potential danger fields before they lead to significant damage.

5- **Interactive visitor experiences:** (IoCT) offers interactive visitor experiences via AR and VR, allowing exploration of historical reconstructions, access to information, and cultural immersion at heritage sites, enhancing visitor engagement.

6- **Real-time alerts and notifications:** Systems are set up to provide real-time alerts and notifications to restoration officials in the event of emergencies or sudden environmental changes that may endanger cultural artifacts or sites.

7- **Collaborative research and data sharing:** (IoCT) enables researchers and experts to collaborate remotely by data sharing, analytics, and insights, leading to a more comprehensive understanding of cultural heritage conservation techniques.

8- **Security and theft prevention:** Using security systems based on (IoT) to monitor heritage sites and protect them from theft or vandalism. Cameras, motion sensors, and controls can help prevent unauthorized access.

9- **Dynamic lighting and display systems:** Install lighting systems controlled by (IoT) that adapt to different times of the day or special events. This can enhance the visual appearance of heritage sites while reducing the effect of light exposure on the artifacts or archaeological sites.

4. CASE STUDY: USING (IOCT) TO PRESERVE THE BUILDINGS OF THE CHURCH OF THE HOLY ARCHANGELS MICHAEL AND GABRIEL - SARAJEVO - BOSNIA AND HERZEGOVINA [32]

In 2006, an ancient Orthodox church complex in Sarajevo, Bosnia and Herzegovina, dating back to the thirteenth or fourteenth century, was declared a national monument, housing valuable cultural artifacts, as shown Fig. 10. Special indicators, including temperature, humidity, ultraviolet radiation, and air pollution sensors, were employed to conserve both movable and immovable heritage at this archaeological site. The remote sensing (ZigBee) network system was used for monitoring, as shown in Fig. 11.

4.1. Using (IoCT) Technologies in Conservation on the Church Building

Modern technologies like (IoT) play a significant role in monitoring and conserving cultural heritage environments, enhancing structural safety, and improving the user and visitor experience[13], [32].

Heritage buildings were conserved to extend their lifespan, with costly restoration of important monuments. (IoCT) played a cost-effective role by deploying air pollution sensors for air quality, humidity, and temperature monitoring. Noise and vibration sensors detected issues from nearby traffic, while ultrasonic sensors assessed building structure damage. Xylophage detectors identified wood insects in wooden components (beams, furniture), and gas and smoke sensors protected against damaging gases, Fig. 12.

Fig. 10. Church buildings inside the cultural heritage site – Sarajevo, Bosnia and Herzegovina

Fig. 11. The remote sensing (ZigBee) network system was used for monitoring [33].

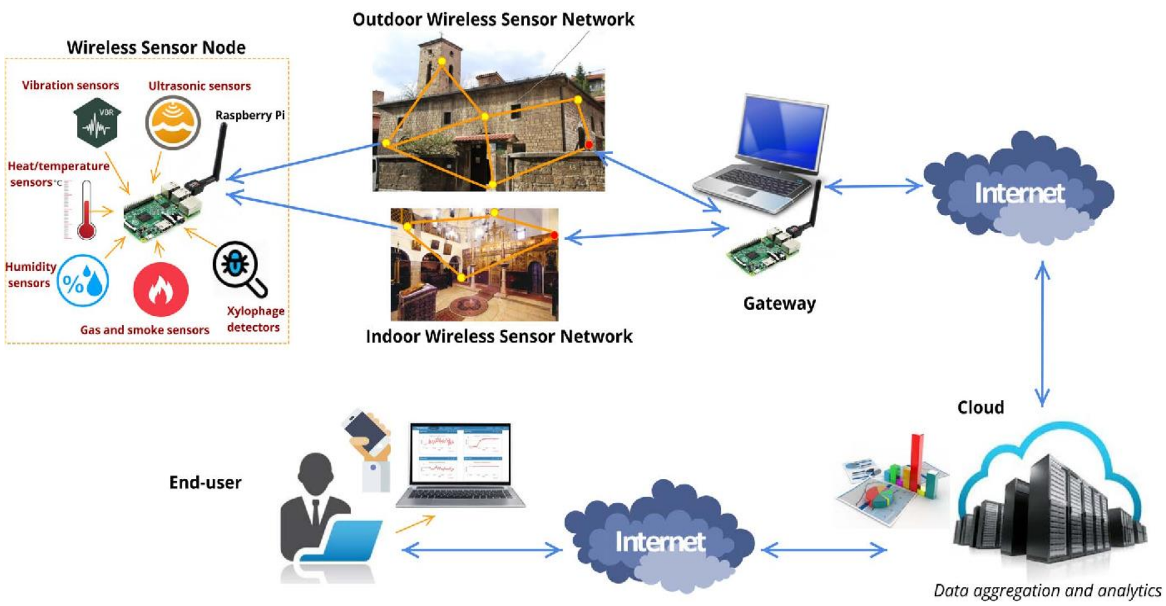

Fig. 12. The general structure of the proposed monitoring system based on (IoT) in the church building[32].

4.2. Steps to Conservation on the Church Building Using (IoT) Cultural Layers

The (IoCT) used in the church building consists of 3 layers, Fig. 13, as follows:

A- The Perception/ Sensing layer - uses affordable, potent sensors to monitor church conditions. These sensors connect to a (Raspberry) Pi board, becoming smart devices with IP addresses, transmitting data to upper layers.

B- Network/ Transmission layer - facilitates data transfer from the Perception/Sensing layer to the upper layer. It employs gateways like PC or Raspberry Pi, supporting data transmission to the cloud. Communication between smart devices is achieved through (ZigBee), Bluetooth Low Energy, or WiFi, enabling real-time data collection and central platform analysis via the Internet, addressing traditional cloud-related challenges.

C- Application layer - manages data processing, storage, and analysis, providing customized applications to end-users. It ensures real-time data collection, sharing, and remote monitoring for timely decision-making, ultimately safeguarding cultural heritage from damage.

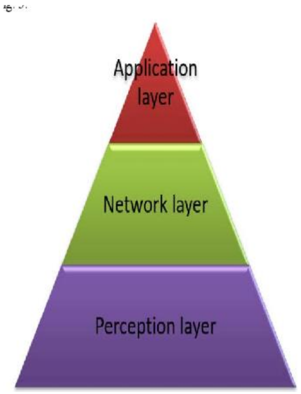

Fig. 13. Layers

5. METHODOLOGY OF (IOCT) IN CONSERVATION ON CULTURAL HERITAGE

When implementing (IoCT) in conservation on cultural heritage, the researcher proposes a methodology and considerations for effectively integrating (IoT) technologies with conservation efforts. It can be taken into account as follows, Fig. 14:

1. **Needs assessment and planning:** Begin by assessing the specific needs and challenges of the cultural heritage site or artifacts you are working with, and identify fields where (IoCT) can have the greatest impact, whether environmental monitoring, security, visitor participation, or documentation.
2. **Choosing an (IoT) device:** (IoT) devices and sensors that are appropriate for the specific requirements of the heritage site are selected. This includes selecting sensors to monitor temperature, humidity, light, vibrations, and more. The devices must also be compatible, reliable, and capable of providing accurate data.
3. **Data Collection, analysis, and integration:** (IoT) sensors gather data on environmental conditions and structural safety, forming a database for analysis. Integration ensures seamless communication between various IoT devices and sensors for valuable data extraction and comprehensive insights.
4. **Real-time monitoring and alerts:** Develop a system that monitoring of environmental conditions, with alerts triggered when conditions exceed predefined limits, allowing immediate response to potential risks.
5. **Remote access and control:** (IoCT) system enables remote access and control, particularly for hard-to-reach sites. It allows remote monitoring, modifications, and conservation efforts, ensuring the protection of artifacts and heritage sites.
6. **Data security and privacy:** Strong security measures are implemented to protect collected data from unauthorized access. It is ensured that sensitive information about cultural heritage is adequately protected.

7. **User-centered design:** By developing interactive experiences for visitors that give priority to user-centered design. Create user-friendly and attractive interfaces that enhance visitor understanding of the heritage site while respecting its cultural value.
8. **Pilot projects:** It is preferable to start with small pilot projects before expanding the scope of (IoT) implementation across a larger heritage site. This gives an opportunity to test, improve, and learn.
9. **Long-term sustainability:** Regular maintenance of devices is taken into account to ensure that the technology remains effective and compatible with evolving conservation needs.
10. **Ethical considerations:** When dealing with cultural heritage, consideration should be given to respecting and without harming the cultural, historical, and social values of those sites while incorporating technology.
11. **Continuous evaluation and improvement:** (IoCT) application involve gathering stakeholder feedback, monitoring the impact of digitizing heritage sites on conservation, and making necessary adjustments for enhanced effectiveness.

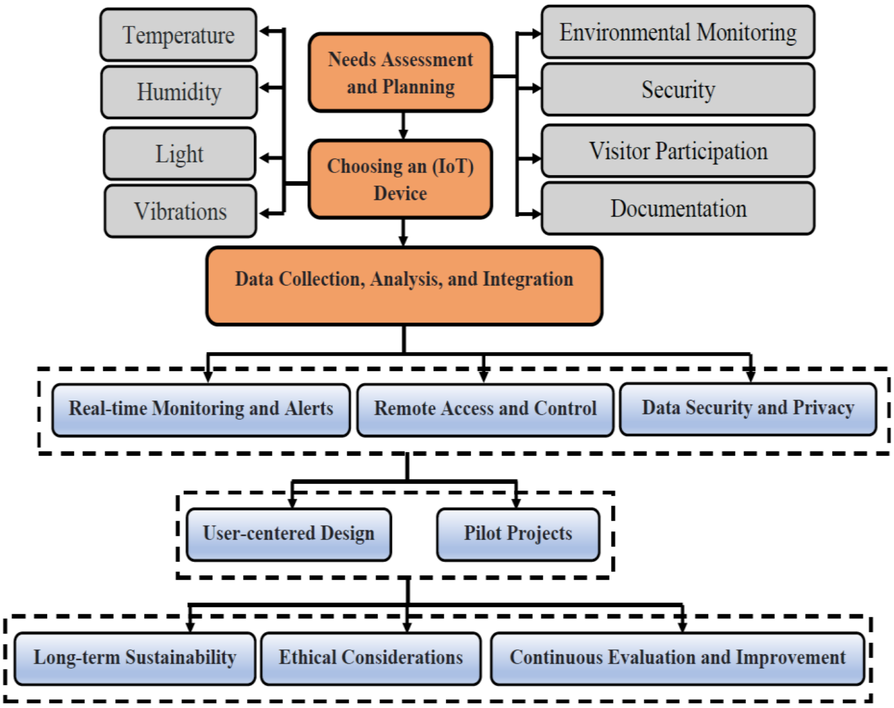

Fig. 14. A proposed methodology for using (IoCT) in conservation on cultural heritage. (Source: author)

6. RESULTS AND DISCUSSIONS

By studying of using (IoCT) technologies like noise, vibration, gas and smoke sensors, etc. to measure air quality, humidity, and temperature. In addition to xylophage detectors to wood insects, and the remote sensing (ZigBee) network system for monitoring lighting controls, Sensors, and Building Systems, in the case study “Church of the Holy Archangels Michael and Gabriel” which show how linking various devices and sensors together then collecting and analyzing data which help in monitoring, maintaining, and conserving cultural heritage site for the church and improving experience of the user and visitor.

Also, The research confirms the possibility of benefiting from the various applications of (IoCT), including the field of conservation on cultural heritage and providing advanced information services within cultural heritage sites, Also the research concentrates on adopting the strategies of (IoCT) and the proposed methodology by the research when dealing with the conservation on cultural heritage sites, taking into account the environmental, climatic, and social considerations and conditions of each heritage site, which may contribute to the continuity of heritage conservation.

Finally, the research indicates the possibility in future research to delve deeper into benefiting from linking smart devices and systems to transform traditional heritage into smart heritage.

7. CONCLUSIONS AND RECOMMENDATIONS

(IoCT) technology integrates cultural heritage with digital data through smart devices and sensors, enhancing conservation efforts. Key research conclusions and recommendations are as follows:

7.1. Conclusions

The research includes the following main conclusions and recommendations:

1. **Enhanced conservation:** (IoCT) enables real-time monitoring of environmental conditions, allowing proactive conservation actions that reduce risks and prevent degradation of heritage sites.
2. **Sharing visitor experiences:** Incorporating interactive elements, such as augmented reality and virtual reality, creates fun and educational visiting experiences, and promotes a deeper connection to cultural heritage.
3. **Data-driven decision making**: The wealth of data collected through (IoT) systems enables officials and decision-makers to make appropriate decisions based on evidence and analyses, leading to more effective conservation strategies.
4. **Collaborative research:** (IoCT) facilitates the exchange of experiences and cooperation between researchers and specialists, which enriches the understanding of cultural heritage for conservation on it.
5. **Sustainability:** Integrating (IoT) into conservation on cultural heritage not only protects precious artifacts but also enhances public participation and dissemination of knowledge of heritage sites for future generations.

Finally, integrating (IoCT) into cultural heritage conservation improves preservation and visitor experiences. (IoT) and smart sensors enhance protection, understanding, and appreciation of heritage sites for future generations.

7.2. Recommendations

1. Participate stakeholders including conservation professionals, archaeologists, architects, and technology experts, to ensure comprehensive (IoCT) implementation that respects the cultural value of heritage sites.
2. Prioritize strong data security measures to protect information on heritage sites and ensure the privacy of visitors and data.
3. Provide continuous training to staff and stakeholders to ensure the effective use and maintenance of (IoCT) systems and promote sustainability to conserve cultural heritage for future generations.
4. Initiate pilot projects to test (IoCT) application on a smaller scale of heritage sites before full deployment, allowing for iterative improvements and modifications.
5. Holding training courses and educational initiatives to raise awareness about the benefits of (IoT) in conservation on cultural heritage among the general public, policymakers, and cultural institutions.
6. Planning for long-term development; by developing a comprehensive long-term plan for maintenance and updates (IoCT) to ensure the continued effectiveness of the technology with continuous evaluation through feedback from visitors, stakeholders, and conservation specialists to improve those strategies and plans.
7. Create online platforms or databases to facilitate collaboration, data sharing, and research among experts working with (IoCT) technologies worldwide.

By adopting these conclusions and recommendations, the potential of (IoCT) can be utilized to conserve on rich cultural heritage, enrich research endeavors, and provide interactive experiences that connect the past and the future.

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