# Preserving Algeria's Cultural Heritage with Blockchain Technology

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**Abstract**

The cultural heritage sector is increasingly turning to innovative techniques to bolster the preservation and management of historical sites and monuments. This article highlights the crucial significance of incorporating blockchain technology alongside Terrestrial Laser Scanning (TLS) in ensuring data integrity during the process of conducting 3D surveys. The application of TLS marks a groundbreaking advancement in valorizing Algeria's cultural heritage. Specifically, it was deployed in documenting the National Museum of Traditional Arts and Cultural Expressions, colloquially known as Ahmed Bey's Palace, an esteemed relic from the Ottoman Empire situated in Constantine, Algeria. Through TLS, meticulous point clouds of the palace were captured and processed using Cyclone software, culminating in the creation of a precise digital replica of the monument. Furthermore, the integration of blockchain technology enhances cultural heritage management and preservation. By leveraging blockchain, the provenance and integrity of TLS-acquired data are securely recorded and preserved from the outset. This ensures transparency and immutability, mitigating concerns related to data tampering or manipulation. Additionally, blockchain facilitates decentralized access management, enabling stakeholders to securely share and collaborate on heritage preservation efforts while upholding data privacy and security. Therefore, the combination of TLS and blockchain is a revolutionary strategy for preserving and advancing Algeria's cultural heritage from the very beginning of preservation efforts.

**Keywords**

Blockchain, Encryption, IPFS, Terrestrial Laser Scanner TLS, Ahmed Bey's Palace, Cultural heritage, Safeguarding and Management, Point cloud

## 1. Introduction

In recent years, the cultural sector has positioned itself as an area, for new investments, in technology [1]. Preserving and managing Algeria's heritage has become increasingly crucial as the nation aims to protect its historical landmarks and monuments. A country's cultural heritage is closely tied to its sense of identity and pride. Whether it be a structure a scenic natural environment or a work of art each represents the collective knowledge and imagination of humanity reaching beyond borders to resonate globally. These treasures act as symbols of our shared cultural traditions uniting people across different eras and locations.

Algeria is a country with a rich cultural legacy that values its history. Every site, whether it be a grand palace or a ruin, tells a story of the fortitude, inventiveness, and unflinching resolve of its people. Algeria recognizes the value of using technology to protect these irreplaceable items for future generations as it tries to preserve its legacy.

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Terrestrial Laser Scanning (TLS) has emerged as a revolutionary tool in the field of cultural heritage preservation, offering unparalleled precision and detail in capturing three-dimensional representations of historical sites and monuments. By employing TLS technology, researchers and conservationists can create digital replicas of these cultural artifacts with unprecedented accuracy, enabling comprehensive analysis and documentation of their structural integrity and historical significance. Furthermore, the integration of blockchain technology introduces a new dimension to the preservation efforts of Algeria's cultural heritage. Blockchain, renowned for its decentralized and immutable nature, serves as an ideal platform for securely recording and preserving the provenance and integrity of TLS-acquired data. Through blockchain, the authenticity of digital representations of cultural artifacts can be assured, mitigating concerns related to data tampering or manipulation. Moreover, blockchain can play a pivotal role in facilitating the digitization and dissemination of cultural heritage assets. By tokenizing digital representations of artifacts and historical sites, blockchain enables fractional ownership and decentralized crowdfunding, empowering communities to collectively support the preservation of their cultural heritage. Additionally, blockchain-based platforms can serve as repositories for digitized cultural content, providing a decentralized infrastructure for archiving and accessing historical records and artifacts.

Several initiatives and projects have already begun to explore the potential of blockchain in cultural heritage preservation. For example, the Digital Archaeological Record (tDAR) [2] project utilizes blockchain technology to track the provenance of archaeological data, ensuring its authenticity and integrity. Similarly, the Museum of the Future in Dubai [3] has announced plans to incorporate blockchain into its operations, including the digitization and tokenization of cultural artifacts.

This article explores the innovative fusion of blockchain technology and 3D scanning, highlighting their transformative impact on Algeria's cultural heritage preservation. By integrating blockchain technology, this research aims to enhance the preservation and conservation efforts of Ahmed Bey’s Palace, ensuring data integrity, provenance, and access management throughout the preservation process. The point cloud data obtained from the TLS scanner serves as the foundation of this endeavor, providing detailed and accurate representations of the palace's structure and features. These point clouds are securely integrated into the blockchain, where they are cryptographically signed and time-stamped to ensure authenticity and traceability. This blockchain integration not only safeguards the integrity of the data but also facilitates decentralized access management, enabling stakeholders to securely share and collaborate on preservation efforts while upholding data privacy and security.

## 2. Background

Prior to delving into our research methodology, it's essential to define the concepts of cultural heritage and Terrestrial Laser Scanning.

### 2.1. Cultural heritage

Cultural heritage encompasses the traditions, customs, artifacts, and values passed down through generations within a community. It can manifest as tangible or intangible expressions of a society's way of life [4]. The European Commission defines cultural heritage as the tangible or intangible cultural and creative assets recognized by society as valuable, preserved for future generations [5]. Cultural institutions are leveraging new technologies to create innovative value propositions, engage audiences, and enhance customer experiences [6].

Ahmed Bey Palace, an Ottoman building located in the historic center (Medina) of the city of Constantine, in northeastern Algeria, was granted the status of Public Museum of Arts and Popular Traditions by the Ministry of Culture in 2010. It was constructed between 1826 and 1833, the architecture and artistic richness of the building are considered an encyclopedia of Arab-Muslim architecture in the Maghreb. The digitization of Ahmed Bey’s Palace has become imperative. This

digital replica, obtained through the BLK scanner, not only enables its archival but also facilitates the comprehension of the palace's evolution and the changes made throughout its historical periods. The digitization of the palace had never been done before and is a first in the cultural sector of Algeria [7].

### 2.2. Terrestrial laser scanning

Our study is built upon the findings presented in the article [7], which employs the TLS 3D BLK 360 Laser Scanner to fully scan the Ahmed Bey Palace. The scanner gathers extensive three-dimensional point cloud data, representing the spatial distribution of objects with coordinates (x, y, z). This data, a survey's raw output, includes details like return intensity and color values, enhancing the scan's depth and accuracy [8]. Figure 1 depict the scanning station positioned both inside and outside of the palace.

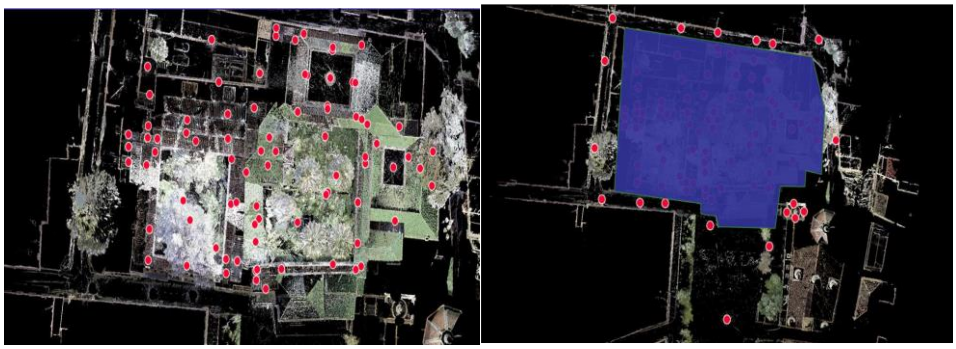

**Figure 1:** Scanning station inside and outside the palace [9].

The Point Cloud is a digital representation of Ahmed Bey's Palace, accurately depicting its scale and dimensions. Stored in RCP format, it comprises millions of points with Cartesian coordinates (Fig. 2), amalgamating multiple scanned files of the monument. This format allows for integration, visualization, and modification in CAD software, benefiting cultural heritage conservation professionals [9]. It serves as a precise documentation tool for the palace's current state and supports restoration, renovation, and management projects. Additionally, it aids in detailed studies of the monument's structure, architecture, historical elements, and evolution over time [10].

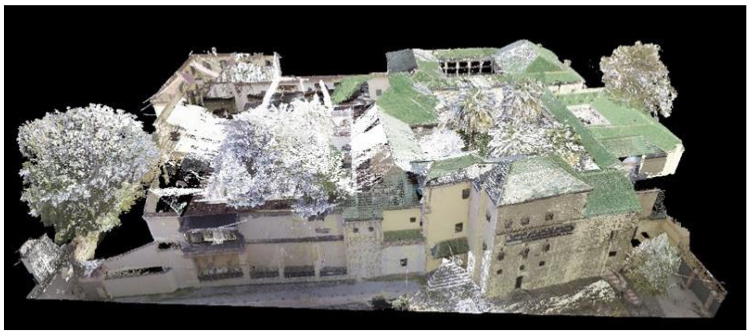

**Figure 2:** 3D Point Cloud model of the Ahmed Bey’s Palace viewing in Cyclone software [7].

## 3. Literature revue

Addressing the challenges of prolonged computation time and subpar registration accuracy encountered in current three-dimensional point cloud registration approaches. The authors in [17] introduce a novel k-dimensional Tree (KD-tree) enhanced Iterative Closest Point (ICP) algorithm known as KD-tree_ICP. This algorithm integrates point cloud filtering and adaptive fireworks algorithms to enhance coarse registration accuracy.

This study [18] explores advancements in cultural heritage preservation through modern documentation techniques, particularly TLS and unmanned aerial vehicle (UAV) photogrammetry. The study highlights the evolving landscape of cultural heritage documentation, demonstrating the benefits of TLS and UAV photogrammetry.

The authors of [19] investigated the application of new digital technology such as laser scanning for 3D mapping to replace conventional historical documentation methods in the protection and restoration of historic monuments. This digital documenting approach collects a wide range of data, including structural, architectural, historical, and non-engineering features, making it an invaluable resource for researchers, architects, and conservationists. They want to examine time series data from monuments using both TLS and TS equipment, and they may incorporate GNSS receivers for big survey sites. This strategy allows them to establish permanent control stations for ongoing data collecting, which improves the accuracy and efficacy of their conservation initiatives.

The authors of [20] used the blockchain to improve the management of intangible cultural heritage archives. By integrating blockchain with distributed ledgers and encryption algorithms, this research aims to develop a specialized file management system for intangible cultural heritage. The author created and developed a RESTful server and a blockchain data management platform, allowing users to engage with cultural data in an understandable and convenient manner. In addition, he has created a system monitoring platform using the Zabbix framework. This platform maintains stability by constantly monitoring the condition of servers and apps and alerting when abnormalities are found. As part of his study, the author intends to develop a completely distributed system capable of effectively managing enormous amounts of data utilizing technologies like MapReduce.

## 4. Proposed system

This section outlines our proposed solution, considering the sensitivity of historical data in the cultural heritage sector. As businesses in this industry explore new ways to improve the protection and management of historical sites and monuments, blockchain technology emerges as a viable solution to current limitations in dispersed systems. Blockchain, leveraging cryptographic hashing and decentralization, establishes a public, immutable digital ledger of time-stamped transactions, ensuring data integrity and security by preventing unauthorized changes and enhancing privacy. The combination of blockchain and TLS is critical in ensuring data integrity during 3D surveys, representing a huge step forward in valuing Algeria's cultural legacy. Using TLS, detailed point clouds of the palace were methodically collected and processed with Cyclone software, resulting in a realistic digital reproduction of this ancient structure. Blockchain's inclusion improves cultural heritage management by securely documenting and maintaining the integrity of TLS-acquired data from the outset, ensuring transparency, immutability, and decentralized access control. This proposed system is illustrated in figure 1.

**a. Data Collection**. The first step involves gathering raw data from our point cloud using the TLS. Given the massive size of this data, it is imperative to securely store it while ensuring its integrity. The output of the data collection process described in the workflow includes:

- ***Raw Data from TLS:*** This is the initial set of data collected from the point cloud using TLS. It comprises detailed spatial information about the scanned object or area.
- ***Metadata:*** Metadata such as scan date, spatial coordinates, and environmental conditions are gathered and associated with the raw data. This metadata provides additional context and information about the scanned data.

**b. Data Preparation**. Point cloud data comes with metadata such as scan date and time, spatial coordinates, environmental conditions, etc. These metadata need to be collected and prepared to be associated with the raw data.

**c. Cryptography and Hashing**. Before recording data on the blockchain, we generate a hash of the raw data using a cryptographic hashing algorithm such as SHA-256. This hash will serve as a unique identifier for the data and ensure its integrity.

d. **Recording Metadata on the Blockchain**. We create a transaction on the blockchain containing the metadata associated with the point cloud data. These metadata can be cryptographically signed to ensure their authenticity. The hash of the raw data is included in this transaction as proof of the existence and integrity of the data. Once recorded on the blockchain, this transaction becomes immutable and can be verified by anyone.
e. **Storing Data on IPFS**. The raw point cloud data is uploaded to the IPFS network. IPFS assigns a unique address called a CID (Content Identifier) to each uploaded file, allowing decentralized referencing and access to the data. We include the CID corresponding to the raw data in the blockchain transaction to provide a link to the data stored on IPFS.
f. **Verification and Data Access**. Users can verify the authenticity of the data by hashing the raw data and comparing it to the hash recorded on the blockchain. If the two hashes match, it confirms the data integrity. Users can also access the raw data by using the CID provided in the blockchain transaction to retrieve the data from the IPFS network.

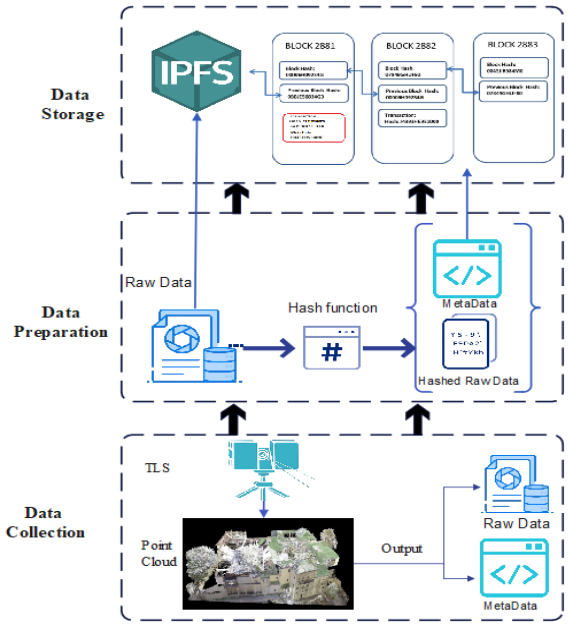


**Figure 3:** Architecture of the proposed system.

## 5. Discussion

The process described above demonstrates a holistic approach to metadata management on the blockchain and secure data storage on IPFS, with an emphasis on TLS for data collection. This integration of emerging technologies addresses crucial data management challenges, particularly for handling large volumes of spatial data while guaranteeing data integrity and accessibility. In our proposition Blockchain technology operates as a decentralized and tamper-proof ledger where transactional data, in this case, TLS data, is recorded in a series of blocks. Once recorded, these blocks are linked together in a chronological and immutable chain, making it virtually impossible to alter or manipulate historical records without consensus from the network participants. At each stage of the TLS data acquisition process, including capturing point clouds, processing, and analyzing the data, relevant information such as timestamps, geospatial coordinates, equipment used, and environmental conditions can be cryptographically signed and recorded on the blockchain. This ensures an auditable trail of data provenance, allowing stakeholders to verify the authenticity and integrity of the collected information. By leveraging blockchain's cryptographic mechanisms, every piece of TLS data is cryptographically hashed and linked to the previous block in the chain. This creates a unique digital fingerprint for each data record, enabling stakeholders to verify its authenticity and trace its lineage back to its origin. Any attempt to modify or tamper with the data would result in a change in the cryptographic hash, alerting the network to potential discrepancies.

The transparent and decentralized nature of blockchain technology instills trust and confidence in the accuracy and reliability of the digital representations of cultural heritage sites derived from TLS data. Blockchain's immutable nature ensures that TLS data recorded on the ledger remains intact and accessible for future generations. As cultural heritage sites evolve over time, having a permanent and tamper-proof record of their digital representations enables ongoing research, conservation efforts, and public access to historical information. As shown in Table 1, our proposal provides an immutable registry, record the data collecting process, guarantee authenticity and traceability, increase trust and assure long-term data preservation. Unlike prior approaches, which did not handle these issues comprehensively, our solution completely incorporates these features by making effective use of blockchain, IPFS, TLS, point cloud, and encryption.

**Table 1**
Comparison of our proposal with related works

| Function | [11] | [12] | [13] | [14] | Our proposal |
|---|---|---|---|---|---|
| Secure and Immutable Ledger | ✗ | ✗ | ✗ | ✓ | ✓ |
| Recording Data Acquisition Process | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ensuring Authenticity and Traceability | ✗ | ✗ | ✗ | ✓ | ✓ |
| Enhancing Trust and Reliability | ✗ | ✗ | ✗ | ✓ | ✓ |
| Long-term Data Preservation | ✗ | ✗ | ✗ | ✓ | ✓ |
| Blockchain | ✗ | ✗ | ✗ | ✓ | ✓ |
| IPFS | ✗ | ✗ | ✗ | ✓ | ✓ |
| TLS | ✓ | ✓ | ✓ | ✗ | ✓ |
| Point cloud | ✓ | ✓ | ✓ | ✗ | ✓ |
| Encryption | ✗ | ✗ | ✗ | ✓ | ✓ |

## 6. Conclusion

This study reveals the powerful combination of blockchain and TLS for maintaining and protecting historical places, representing a significant advancement in the cultural heritage sector. The comprehensive digital recreation of Ahmed Bey's Palace demonstrates how TLS is transforming cultural heritage documentation. Blockchain integration improves both data management efficiency and anonymity in cultural asset conservation. Immutable blockchain records protect data integrity, lowering the danger of manipulation. Furthermore, blockchain's decentralized access control promotes cooperation while ensuring data security and privacy. This collaboration not only saves cultural history, but also opens the way for innovative preservation methods throughout the world, emphasizing the importance of technology in maintaining cultural legacy for future generations.

## Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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