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The mechanism of digital documentation and upgrading for the historical buildings and restoring their historical status using 3D scanning technology and projection mapping facades

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Abstract: This paper discusses the mechanism of digital documentation and upgrading for historical buildings using 3D scanning technology and projection mapping facades. It reviews the current state-of-the-art documentation technologies and emphasizes the importance of careful planning and consideration of the documentation process and its objectives. The digital documentation of heritage buildings is seen as a two-phase procedure, involving the acquisition of necessary data using various data capture tools. The documentation process incorporates a diverse range of data formats, from quantitative to qualitative and tangible to intangible. Additionally, the paper explores the use of digital technologies such as photogrammetry and laser scanning for three-dimensional modeling and compares them to the current standard. It also addresses the feasibility of a universal file format for archival purposes and discusses progress towards this goal. A case study of the Egyptian museum in Cairo, Egypt, is presented to demonstrate the application of laser scanning technology in the digital documentation process. The paper further discusses heritage building information modeling (HBIM) principles and their application in digital documentation. Overall, this manuscript provides a comprehensive overview of digital documentation and upgrading for historical buildings, covering various aspects of the process and presenting case studies to illustrate the application of digital technologies in historic documentation.

1. Introduction

The digital documentation of heritage buildings is a crucial process that involves the acquisition of necessary data using various data capture tools. The documentation process incorporates a diverse range of data formats, from quantitative to qualitative and tangible to intangible. The use of digital technologies such as photogrammetry and laser scanning for three-dimensional modeling is becoming increasingly popular and is being compared to the current standard. The importance of careful planning and consideration of the documentation process and its objectives is emphasized. This paper aims to provide a comprehensive overview of digital documentation and upgrading for historical buildings, covering various aspects of the process and presenting case studies to illustrate the application of digital technologies in historic documentation. The paper reviews the current state-of-the-art documentation technologies and emphasizes the importance of careful planning and consideration of the documentation process and its objectives. The digital documentation of heritage buildings is seen as a two-phase procedure, involving the acquisition of necessary data using various data capture tools. The documentation process incorporates a diverse range of data formats, from quantitative to qualitative and tangible to intangible. Additionally, the paper explores the use of digital technologies such as photogrammetry and laser scanning for three-dimensional modeling and compares them to the current standard. It also addresses the feasibility of a universal file format for archival purposes and discusses progress towards this goal. A case study of the Egyptian museum in Cairo, Egypt, is presented to demonstrate the application of laser scanning and the projection mapping technology in the digital documentation process [1].

The research further discusses heritage building information modeling (HBIM) principles and their application in digital documentation. The literature review also highlights the challenges of digital building data usage with a focus on the digital documentation of heritage buildings. [2]

The study discusses the need for standardization in documentation and the importance of data interoperability. The paper proposes a hierarchy of records for the digital meta-documentation of buildings for architectural or archaeological history. The study also emphasizes the importance of digital documentation in heritage conservation, providing comprehensive records of heritage sites and aiding in practical conservation and restoration plans while making cultural heritage accessible to broader societies [3]

In general, this research provides a comprehensive overview of digital documentation and upgrading for historical buildings, covering various aspects of the process and presenting case studies to illustrate the application of digital technologies in historic documentation. The review emphasizes the importance of careful planning and consideration of the documentation process and its objectives, and the need for standardization and data interoperability. The review also highlights the challenges and benefits of digital documentation in heritage conservation.

2. Literature Review

The digital documentation of heritage buildings is a crucial process that involves the acquisition of necessary data using various data capture tools. The documentation process incorporates a diverse range of data formats, from quantitative to qualitative and tangible to intangible. The use of digital technologies such as photogrammetry and laser scanning for three-dimensional modeling is becoming increasingly popular and is being compared to the current standard [2]. The importance of careful planning and consideration of the documentation process and its objectives is emphasized. In Egypt, the current practice mainly depends on 2D documentation techniques, with the data being acquired with traditional survey works and photogrammetry. However, these methods are time-consuming, labor-intensive, and prone to human error. Moreover, they are not practically adequate to capture all the fine details and imperfections of the antiquities. To overcome these challenges, researchers are exploring the use of LIDAR and HBIM technologies through a flexible framework suitable for Egyptian Heritage Documentation efforts.[4]

The documentation of heritage buildings is the preliminary action to deal with any problem related to the built heritage. The procedure of documentation requires a very diverse range of data formats, from quantitative to qualitative and tangible to intangible [1]. Current state-of-the-art documentation technologies are already available and capable of delivering accurate and reliable information if accompanied with careful planning and consideration of the documentation process and its objective. These technologies cover a wide range of targeted data that are useful in various aspects of a heritage building and its required interventions [2].

A case study of the Egyptian Museum in Cairo, Egypt, illustrates the application of laser scanning technology in the digital documentation process and the application of a new way of displaying historical events on the facade of the building. The main goal of the current study is to develop the process of digital documentation using laser scanning, which is one of the most famous historical monuments in Egypt, and to develop methods of monumental display in Egypt to keep pace with modern technology, by obtaining a three-dimensional model of the building and then using it to determine the coordinates to apply map projection technology. The three-dimensional digital model of the building that will be obtained includes engineering data, structural, architectural and historical details, in addition to non-engineering data.

In conclusion, offers a thorough summary of the modernization and digital documenting of historic structures, addressing all facets of the procedure and showcasing case examples to demonstrate how digital technologies are used in historical documentation. The assessment places a strong emphasis on the necessity of standards and data interoperability, as well as the significance of carefully organizing and considering the documentation process and its goals. The evaluation also illustrates the use of contemporary display technology to boost the tourist appeal of structures that are starting to disappear and the difficulties and advantages of digital documenting in heritage conservation.

2.1.Projection mapping façade.

Projection mapping facade technology is a technique that utilizes projectors to project images, videos, animations, and light onto the surfaces of building facades, creating dynamic and visually captivating displays [5]. Projection mapping appeared in the 2000s and has since become a popular method for turning objects and elements into display surfaces for video projection. (as shown in Fig.1)

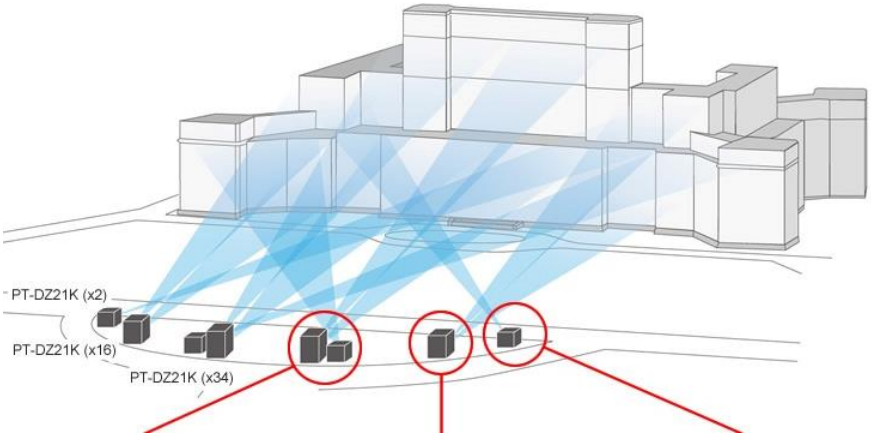

Fig. 1 projectors have previously been used for high profile display "The facade of the Palace of Parliament " Romania. [6]

- **2D and 3D Mapping:** The objective of mapping is to create optical illusions by putting visual content on static volumes. The projection surface is the fundamental distinction between 2D and 3D projection mapping.
- **Projection Surfaces:** Projection mapping surfaces are infinitely varied, ranging from the facade of a monument to an architectural detail, from a stage set to a small object or a simple wall.
- **Software:** There are various software options available for creating projection mapping displays, such as Heavy, which is reliable, powerful, and works with any kind of projector and MAC/Windows compatible.
- **3D Projection Mapping:** 3D projection mapping is popular these days and can be used on basically any surface that catches light, from bridges and buildings to cars and trees.
- **3D Modelling:** Building projection mapping requires an accurate 3D model of your building, which can be made using laser scanning.
- **Trial and Error Production:** The final stage of building projection mapping is on-site and entails a lot of trial and error. Lighting, proportions, alignment, and blending will all be tested until the projected image perfectly fits the facade of the building.

In summary, projection mapping facade technology is an engaging and flexible technique that has gained popularity in recent years. It involves the use of projectors to project visual content onto building facades, creating dynamic displays that can transform architectural structures and other objects into visually engaging experiences.

2.2.Interactive facade projection mapping.

Interactive facade projection mapping blends projection mapping techniques with interactive components, allowing attendees to actively interact with the projected content on the building facades and different ways of interacting with the users. (as shown in Fig.2)

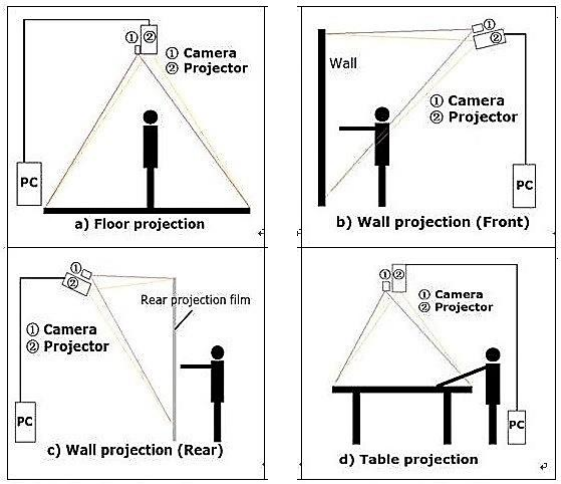

Fig.2 Interactive projection mapping techniques in different ways diagram. [7]

The following are some essential details about interactive facade projection mapping:

- Interactive facade projection mapping is a technique that combines projection mapping with interactive elements, allowing viewers to actively engage with the projected content on the building façade.
- The technique is becoming increasingly popular in the tourism sector and is helping tourists interpret and understand tourist sites.
- The process involves the use of media processing units that can automatically scan the projection surfaces and calculate soft edge blending and the geometry correction. [8]
- The technique is used for a variety of different applications ranging from live shows and events to interactive and themed attractions.
- Interactive facade projection mapping can be used as a spatial augmented reality to help collaborative design in architecture and engineering.
- The technique can also be used to improve visual comfort based on dynamic daylight and occupant's positions by 2D and 3D shape changes. [9]

Overall, through the use of interactive features and projection mapping, viewers are able to actively interact with the content projected onto building facades. The technique is becoming increasingly popular in the tourism sector and is used for a variety of different applications ranging from live shows and events to interactive and themed attractions. The technique can also be used as a spatial augmented reality to help collaborative design in architecture and engineering and to improve visual comfort based on dynamic daylight and occupant's positions by 2D and 3D shape changes.

2.3.Types of projection mapping.

While projection mapping techniques and applications come in many forms, the following are some popular types:

- **Standard Video Mapping:** This is the most common type of projection mapping, where pre-programmed 3D graphics, animations, and visual content are projected onto a static surface, such as a building facade or an object. The content is carefully aligned and mapped to fit the surface, creating the illusion of dynamic and interactive visuals.
- **Interactive Projection Mapping:** In interactive projection mapping, the projected content responds to real-time input or interactions from the audience. This can involve motion sensors, touch-sensitive surfaces, or even facial recognition technology. The interactive elements allow viewers to actively engage with the projection mapping display, creating a more immersive and participatory experience.
- **Augmented Reality (AR) Projection Mapping:** AR projection mapping combines projection mapping with augmented reality technology. Virtual elements are projected onto physical surfaces, enhancing the real-world environment with digital content. This can include overlaying information, animations, or interactive elements onto buildings or objects, creating a blended reality experience.

- **Live Performance Projection Mapping:** Live performance projection mapping involves real-time projection mapping during live events, such as concerts, theatre performances, or art installations. The visuals are synchronized with the live performance, creating a dynamic and immersive visual spectacle that enhances the overall experience for the audience.
- **Architectural Projection Mapping:** Architectural projection mapping focuses specifically on transforming the facades of buildings through projection mapping techniques. It allows for the manipulation of the building's architectural features, textures, and surfaces, turning them into dynamic canvases for storytelling and visual displays.
- **Object Mapping:** Object mapping involves projecting visuals onto three-dimensional objects, sculptures, or installations. The content is carefully aligned and mapped to fit the surfaces of the objects, bringing them to life with dynamic visuals and animations. [10]
- **Table Mapping:** Table mapping is a unique form of projection mapping where the visuals are projected onto a tabletop surface. This can be used to create interactive and engaging experiences during events, dinners, or product launches, where the table itself becomes a canvas for storytelling and visual displays.
- **Interior Mapping:** Interior mapping focuses on projecting visuals onto the interior surfaces of a space, such as walls, ceilings, or floors. This can be used to transform the atmosphere of a room, create immersive environments, or enhance architectural features within the interior space.
- **Site-Specific Mapping:** Site-specific mapping involves tailoring the projection mapping content to a specific location or environment. This can include landmarks, historical buildings, or natural landscapes, where the visuals are designed to complement and interact with the unique characteristics of the site.

These are just a few examples of the types of projection mapping techniques used in various contexts. The choice of projection mapping type depends on the desired effect, the nature of the project, and the specific goals of the visual display.

2.4.Technology of projection mapping.

The technology of projection mapping façade technology to produce visually attractive displays on building facades, specialized equipment is needed. These are a few instances of the typical tools used in projection mapping: (as shown in Fig.3)

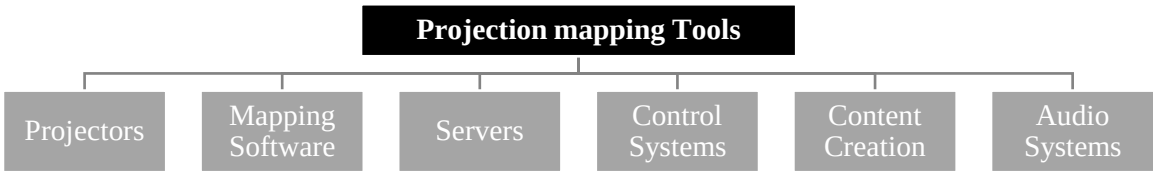

Fig. 3 Chart of the Projection mapping tools.

- **Projectors**: For projection mapping, top-notch projectors are necessary. For vivid and clear images, they should have enough brightness, resolution, and contrast. Depending on the scope and intricacy of the projection mapping project, several projectors may be employed.
- **Mapping Software**: The projected content is spatially mapped onto the building façade surfaces using specialized mapping software. The projected pictures or videos may be precisely aligned and calibrated with the help of this program. [11]
- **Media servers:** are employed to record and replay the material that is displayed on the exterior walls. They provide the required processing power and synchronization capabilities to enable smooth and continuous playing.
- **Content Creation applications**: To create and modify the content that will be projected onto the facade, a variety of software applications are available. With the use of these technologies, artists may synchronize audio, create and animate graphics, and include interactive components.
- **Control Systems**: The projection mapping setup is managed and controlled by control systems. They make it possible for several projectors, media servers, and mapping software to all operate in unison, guaranteeing a well-planned and seamless visual experience.

- **Audio Systems**: To improve the immersive experience, audio systems may occasionally be incorporated into the projection mapping arrangement. To deliver synchronized sound effects or music, speakers may be positioned thoughtfully across the facade.

2.5. 3D laser scanning technology and digital image photogrammetry.

Two popular methods used for creating accurate digital models of real-life objects, people, or spaces [4]. It is an efficient way to create accurate digital replicas of physical objects. The laser scanner operates by firing millions of light pulses, counting the number of objects each light pulse strikes, and calculating the distance between them. It can be used for a variety of applications ranging from 3D printing to projects that need a precise digital model of an object or space. Structured light works well for the 3D scanning of objects and detecting specific shapes, sizes, and textures. It can handle big projects that can help with global developments, like space and environmental projects.

2.6. Digital Image Photogrammetry

It is a process that takes digital photos and converts them into 3D models. It is often used in fields such as construction, engineering, archaeology, and more. It can help businesses get a better understanding of the space they are working with before they start building or remodelling their property. It can also be used to produce 3D models for use in animation, games, and virtual reality applications.[4] It requires no 3D scanner and can be completed using pictures taken with anything from a handheld smartphone to a drone.

Overall, 3D laser scanning technology and digital image photogrammetry are two popular methods used for creating accurate digital models of real-life objects, people, or spaces. 3D laser scanning is an efficient way to create accurate digital replicas of physical objects, while photogrammetry is a process that takes digital photos and converts them into 3D models. Both methods have their advantages and limitations, and the choice of method depends on the specific requirements of the project and the available budget.

2.7.3D Geoscan:

This business focuses on modeling apps for the CAD, GIS, BIM, and 3D sectors, and digital twin intelligence to all sectors. The company provides reliable state-of-the-art 3D geospatial end-to-end solutions, including mobile data collection, 3D scanning, and reality modelling applications. It's solutions are used in a variety of industries, including construction, engineering, architecture, and more. The company's 3D scanning technology is used to create accurate digital models of real-life objects, people, or spaces. It's reality modelling applications can be used to produce 3D models for use in animation, games, and virtual reality applications. The company's mobile data collection solutions can be used to collect data in the field and create accurate digital models of real-life objects, people, or spaces.[12]

Overall, 3D Geoscan offers dependable, innovative 3D geospatial end-to-end solutions, such as apps for reality modeling, mobile data collecting, and 3D scanning serving CAD, GIS, BIM, 3D markets, and digital twin intelligence to all sectors. The company's solutions are used in a variety of industries, including construction, engineering, architecture, and more. It's 3D scanning technology and reality modeling applications can be used to create accurate digital models of real-life objects, people, or spaces, while their mobile data collection solutions can be used to collect data in the field.

2.8. 3D Representation

It refers to the process of creating a mathematical coordinate-based representation of any surface of an object in 3D space.

It is the foundation for computer graphics, computer-aided geometric design, and other related fields. It provides a way to represent 3D objects in a computer, allowing for the construction of such representations quickly and/or automatically with a computer. There are different methods for different object representations, including raw data, surfaces, and high-level structures. Raw data representation includes point clouds, range images, and polygon soup. Surface representation includes mesh, subdivision, parametric, and implicit. High-level structure representation includes

scene graph, skeleton, and application-specific. It can be created manually, algorithmically, or by scanning. It can be used in various industries like film, animation, gaming, interior design, architecture, and the medical industry. [13]

There are different types of 3D data representations, including multi-view representations, point clouds, meshes, parametric models, depth-maps, RGB-D, and voxels. Overall, 3D representation is a crucial process that provides a way to represent 3D objects in a computer, allowing for the construction of such representations quickly and/or automatically with a computer. There are different methods for different object representations, and 3D representation can be created manually, algorithmically, or by scanning. 3D representation can be used in various industries, and there are different types of 3D data representations to choose from.

2.9.The documentation process can be divided into two main phases:

- **Data acquisition:** This involves the use of various data capture tools, such as laser scanners, photogrammetry cameras, and traditional survey equipment. The choice of tools depends on the specific requirements of the project and the available budget.
- **Data processing and analysis:** This involves the processing and analysis of the acquired data to generate a comprehensive digital model of the heritage building. [13]

  This may include the use of software tools for point cloud registration, mesh generation, and texture mapping, as well as the extraction of geometric, structural, architectural, and historical details.

2.10. Methodology

The digital documentation of heritage buildings is a crucial process that involves the acquisition of necessary data using various data capture tools. The documentation process incorporates a diverse range of data formats, from quantitative to qualitative and tangible to intangible. The use of digital technologies such as photogrammetry and laser scanning for three-dimensional modeling is becoming increasingly popular and is being compared to the current standard. [4]

The importance of careful planning and consideration of the documentation process and its objectives is emphasized. In Egypt, the current practice mainly depends on 2D documentation techniques, with the data being acquired with traditional survey works and photogrammetry.

The method of 3D scanning is used to digitally represent items in three dimensions by capturing their look and shape. Heritage buildings have been scanned using this technique, and the 3D models have subsequently been projected onto the building façade for projection mapping displays. Systems that can be used and exploited in Egypt in planning, improving, treating, rehabilitating and raising the efficiency of facades in Egypt to achieve an aesthetic element that suits Egyptian culture, identity, and economic capabilities, and their optimal use in the field of archaeological and heritage buildings within the framework of stimulating tourism and giving a kind of dynamism to those facades and using them in explaining history. (as shown in Fig.4)

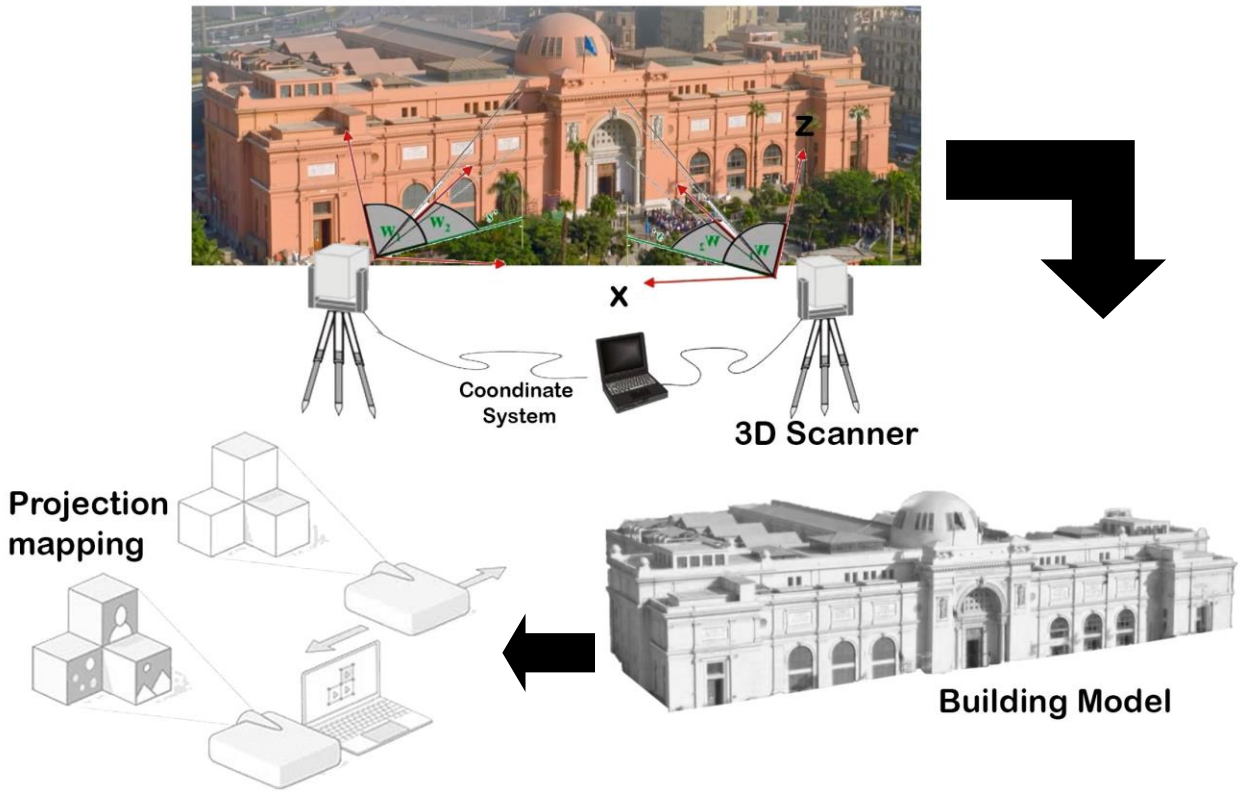

Fig. 4 diagram showing the process of the digital mechanism.

However, these methods are time-consuming, labor-intensive, and prone to human error. Moreover, they are not practically adequate to capture all the fine details and imperfections of the antiquities. To overcome these challenges, researchers are exploring the use of LIDAR and HBIM technologies through a flexible framework suitable for Egyptian Heritage Documentation efforts.

A proposal for the shape of the museum facade after projections were made on the facade of the building at night. (as shown in Fig.5)

Fig. 5 Final rendering for museum facade after the projection mapping process.

3. Conclusions

In conclusion, This study has studied the method of digital documenting and updating for historical structures utilizing 3D scanning technology and projection mapping facades. A thorough digital model of the object or area must be created once the essential data has been gathered using a variety of data capture techniques. This two-phase process is known as digital documentation of heritage structures. A wide variety of data forms, both quantitative and qualitative, physical and intangible, are included in the documentation process. A uniform file format for archiving reasons has been addressed, and the use of digital technologies like photogrammetry and laser scanning for three-dimensional modeling has been investigated.

To illustrate the use of laser scanning technology in the digital documenting process, a case study of the Egyptian museum in Cairo, Egypt, has been provided.

The ideas of heritage building information modeling (HBIM) and how they apply to digital documentation are covered in further detail in the research. This publication offers a thorough overview of the process of digital recording and updating for historical structures. It covers a number of different issues and presents case studies that demonstrate how digital technologies are applied in historic documentation.

- Improved tourist Experience: By incorporating dynamic graphics and interactive components into the building's front, projection mapping may improve the overall tourist experience.
- Preservation of Heritage: In addition to offering a platform for artistic expression, projection mapping enables the celebration and preservation of a building's architectural legacy.
- Storytelling: To engage and educate visitors, projection mapping may be used to present tales about the heritage building's significance, history, or culture.
- Flexibility: The ability to display a variety of images, animations, and multimedia components makes projection mapping flexible with regard to themes and content.
- Temporary and Safe: Since projection mapping doesn't necessitate long-term structural modifications, it is a transient and non-invasive method of altering a heritage building's exterior..

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