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CONCEPT OF INFORMATION SYSTEM FOR CULTURAL HERITAGE SITES RENOVATION USING AUGMENTED REALITY

Cultural heritage is key to identity and development. Many valuable objects are affected by time, natural elements and financial lack. Innovative technologies are crucial for their preservation. The paper develops an information system based on augmented reality (AR) for the restoration of cultural heritage. This extends AURA's approach to preserving musical spaces by applying AR to cultural objects. New techniques improve AURA, allowing accurate restoration of objects affected by time. 3D modeling and machine learning allow to create virtual replicas with precision down to the smallest detail. Augmented reality and machine learning open new perspectives for the preservation of cultural values. The paper proposes an innovative approach of using AR for cultural heritage restoration. The authors offer unique solutions for accurate modeling of 3D models of objects. The purpose of the paper is to develop an information system for the restoration of cultural heritage through AR. This will increase the possibilities of preservation and research of values. Using AR and 3D modeling can improve the restoration of objects and provide access for researchers and the public. In future research, the proposed approaches and methods will be implemented to expand the functionality of the information system. This will include developing interactive interfaces for interacting with virtual models of cultural heritage, analyzing data for a deeper understanding of restoration processes and trend detection, as well as integrating cutting-edge information technologies, such as virtual reality and natural language recognition systems, using artificial intelligence. The primary goal is to improve the processes of preserving and studying cultural heritage through the use of modern information technologies.

Keywords: cultural heritage, restoration, innovative technologies, augmented reality (AR), machine learning, 3D modeling, information technologies.

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КОНЦЕПЦІЯ ІНФОРМАЦІЙНОЇ СИСТЕМИ РЕСТАВРАЦІЇ ОБ’ЄКТІВ КУЛЬТУРНОЇ СПАДЩИНИ З ВИКОРИСТАННЯМ ДОПОВНЕНОЇ РЕАЛЬНОСТІ

Культурна спадщина є ключовою для ідентичності та розвитку. Багато цінних об'єктів загрожують час, природні стихії і фінансова відсутність. Інноваційні технології є вирішальними для їх збереження. Стаття розробляє інформаційну систему, засновану на доповненій реальності (AR), для реставрації культурної спадщини. Це розширює підхід AURA, спрямований на збереження музичних просторів, застосовуючи AR для культурних об'єктів. Нові методи покращують AURA, дозволяючи точну реставрацію об'єктів, що зазнають впливу часу. 3D-моделювання та машинне навчання дозволяють створювати віртуальні копії з точністю до деталей. Доповнена реальність та машинне навчання відкривають нові перспективи для збереження культурних цінностей. Стаття пропонує інноваційний підхід використання AR для реставрації культурної спадщини. Автори пропонують унікальні рішення для точного моделювання 3D-моделей об'єктів. Мета статті - розробити інформаційну систему для реставрації культурної спадщини через AR. Це дозволить збільшити можливості збереження та дослідження цінностей. З використанням AR та 3D-моделювання можна покращити реставрацію об'єктів та забезпечити доступ для дослідників і публіки. У подальших дослідженнях запропоновані підходи та методи будуть реалізовані для розширення функціональності інформаційної системи. Це включатиме розробку інтерактивних інтерфейсів для взаємодії з віртуальними моделями культурної спадщини, аналіз даних для глибшого розуміння процесів реставрації та виявлення тенденцій, а також інтеграцію передових інформаційних технологій, таких як віртуальна реальність та системи розпізнавання природної мови, з використанням штучного інтелекту. Основною метою є вдосконалення процесів збереження та вивчення культурної спадщини шляхом використання сучасних інформаційних технологій.

Ключові слова: Культурна спадщина, реставрація, інноваційні технології, доповнена реальність (AR), машинне навчання, 3D-моделювання, інформаційні технології.

Introduction

Cultural heritage is the foundation that unites people with the past and defines their identity. It plays a crucial role in strengthening social cohesion and promoting cultural development. However, many cultural heritage sites gradually deteriorate due to the effects of time, natural disasters, and insufficient funding for their restoration and conservation. In this context, new technologies, such as Augmented Reality (AR) and Machine Learning, become increasingly important, offering innovative solutions for preserving and restoring cultural heritage. Therefore, this article is aimed at developing such an innovative information technology based on AR for the renovation of cultural heritage sites.

The proposed methods in the concept will enhance the achievements of the AURA project, providing impeccable renovation and reproduction of cultural heritage sites that may be lost or destroyed over time. Advanced technologies, such as 3D modeling and Machine Learning, enable the creation of accurate virtual replicas of real objects while preserving their original shape, texture, color, and materials.

Moreover, the application of Augmented Reality in combination with object recognition and Machine Learning algorithms opens up countless new possibilities for the restoration, preservation, and visualization of cultural treasures for present and future generations.

The rest of the paper is structured in the following way. In Section Related work the analysis of recent related works in the domain is performed. In Section Architecture of Information System, the key methods are identified and three fundamental functions of the information system are formed. In Section Case Study the experimental part is described. A Section Conclusions summarizes the received results.

Related work

In this domain, numerous research works have already been conducted, which combine two key themes: the use of Augmented Reality (AR) and Virtual Reality (VR) technologies in the context of architecture and cultural heritage. Several relevant studies analyze the potential of these technologies, including their impact on understanding architectural space [2] and their wide range of applications in the field of cultural heritage [3, 6]. Even specific examples of VR/AR applications that enhance interaction with cultural heritage objects are presented [4, 5].

AR-oriented research includes the development of an AR taxonomy for art and cultural heritage [7], the presentation of an AR-based visualization system for cultural heritage objects [8], the use of photogrammetry and AR for reproducing cultural objects [9], the creation of an AR system to enhance users' knowledge of cultural heritage [10], and methods of multispectral 3D recording and documentation for the development of mobile applications dedicated to cultural heritage [11].

The concept of an information system for the restoration of cultural heritage objects through augmented reality is an extension of the ideas of the AURA project [1], which already uses technologies for the analysis and preservation of musical and cultural spaces. The AURA project focuses on creating acoustic models of music venues and researching their impact on sound, while the new concept uses augmented reality for the reproduction and preservation of significant cultural objects.

This research presents an innovative approach to using augmented reality in the context of cultural heritage restoration compared to existing solutions, including the development of specialized methods and technologies. The authors propose unique solutions that involve precise modeling, identification, and creation of 3D models of cultural monuments.

The purpose of this article is to develop the concept of an information system for the renovation of cultural heritage objects using augmented reality, as discussed below.

Architecture of Information System

The authors have conducted a series of previous research studies on the application of advanced information technologies, including Augmented and Virtual Reality, Machine Learning, and 3D modeling, in various domains [12, 13]. Taking this into account, as well as the expected results of cultural heritage object renovation, the following key methods are identified:

- method of Enhancing 3D Models of Cultural Heritage Objects: This method involves precise and detailed reproduction of the shape, color, texture, and materials of cultural objects in the 3D models;
- method of Recognizing Specific Cultural Heritage Objects based on Machine Learning algorithms, which will recognize and classify objects in the real world;
- method of Generating Specific Cultural Heritage Objects, which involves creating 3D models of virtual replicas of cultural objects with accurate representation of original colors, textures, and other details;
- method of Determining the Correct Placement of Objects, which will utilize orientation sensors and object recognition to determine where the virtual object should be placed in the real world.

The analysis of these methods enables to form the three fundamental functions of the information system: data collection, virtual restoration, and interactivity. Based on the content of these functions, the architecture of the information system for the renovation of cultural heritage objects can be synthesized (Figure 1).

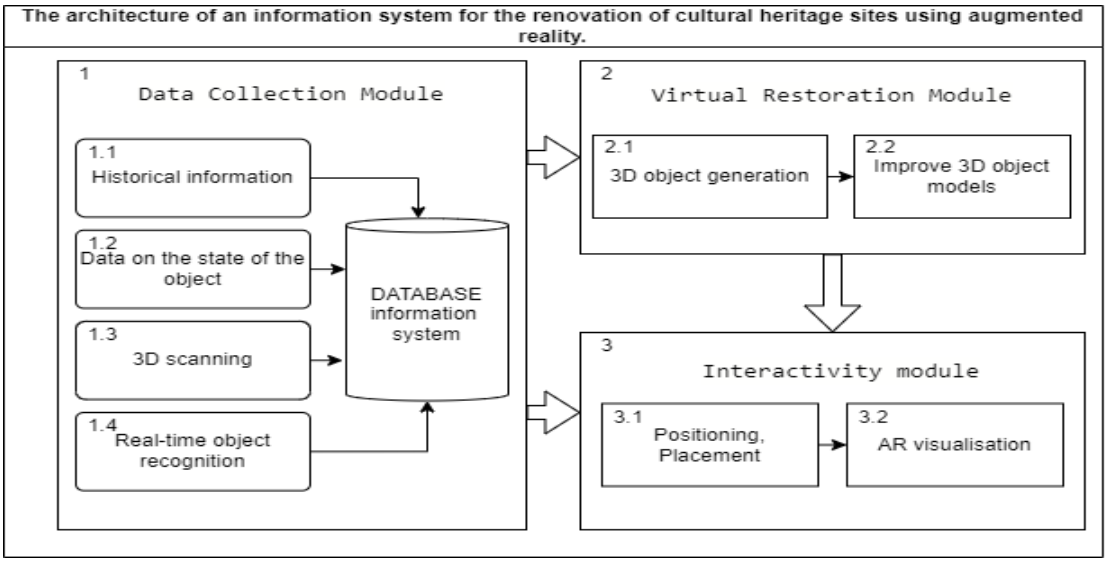


Fig. 1. Architecture of the Information System for Cultural Heritage Objects Renovation

Let's take a closer look at the components of the architecture. The Data Collection Module (Block 1) ensures the gathering of all necessary information about cultural heritage objects and includes the following sub-blocks:

Historical Information (Block 1.1): Collects historical data about the object, including its origin, usage history, significance, and other important details.

Object Condition Data (Block 1.2): Gathers information about the current condition of the object, including any damages, changes, or other issues that may affect the restoration process.

3D Scanning (Block 1.3): Utilizes 3D scanning technologies to create detailed 3D models of the object, which can be used for virtual restoration.

Real-time Object Recognition (Block 1.4): Employs machine learning algorithms for real-time recognition and classification of objects in the real world. All these blocks contribute to the Information System Database.

The Virtual Restoration Module (Block 2) is responsible for the virtual restoration of cultural heritage objects. It includes the following sub-blocks:

Object 3D Generation (Block 2.1): Utilizes 3D modeling technologies to create virtual replicas of cultural heritage objects.

Enhanced 3D Object Models (Block 2.2): Utilizes various techniques and algorithms to enhance 3D models, ensuring precise reproduction of the object's shape, color, texture, and materials.

The Interactivity Module (Block 3) focuses on user interaction with virtual cultural heritage objects and consists of the following sub-blocks:

Positioning and Placement (Block 3.1): Uses orientation sensors and object recognition to determine where the virtual object should be placed in the real world.

AR Visualization (Block 3.2): Employs augmented reality technologies to visualize virtual objects in the real world, allowing users to interact with them in real-time.

This concept has the potential to significantly improve the restoration and preservation processes of cultural heritage objects. Augmented reality can enable a deeper and more effective engagement of researchers, restorers, and even the general public with the process of renovation and preservation of cultural heritage.

These modules play crucial roles in the renovation and restoration of cultural heritage objects. They work together to ensure precise reproduction of objects, effective recognition and classification, and interactive engagement with the objects.

Users of the system could include scholars, restorers, and the general public who can use these technologies to explore, restore, and appreciate cultural heritage objects in new ways.

Compared to existing solutions, this research represents a conceptually novel approach to using augmented reality for cultural heritage renovation, including the development of specific methods and technologies. Unique solutions are proposed, including precise reproduction, recognition, and generation of 3D models of cultural heritage objects.

This will improve the understanding and interaction with cultural heritage objects, ensuring their restoration and preservation for future generations.

Case Study

Case 1: "Virtual Restoration of Cultural Heritage Using 3D Modeling"

The restorer opens the application on their computer and enters their login credentials to access the system. The system recognizes the restorer and provides them with full access to all functionalities.

The restorer selects an object for virtual restoration from the system's database. The system loads the 3D model of the object and all available information about its condition, history, and other important details (Figure 2).

The restorer utilizes the system's tools to model the restoration process, including repairing damages, restoring lost details, etc. Once the restoration is complete, the system saves the enhanced 3D model of the object for future use and analysis.

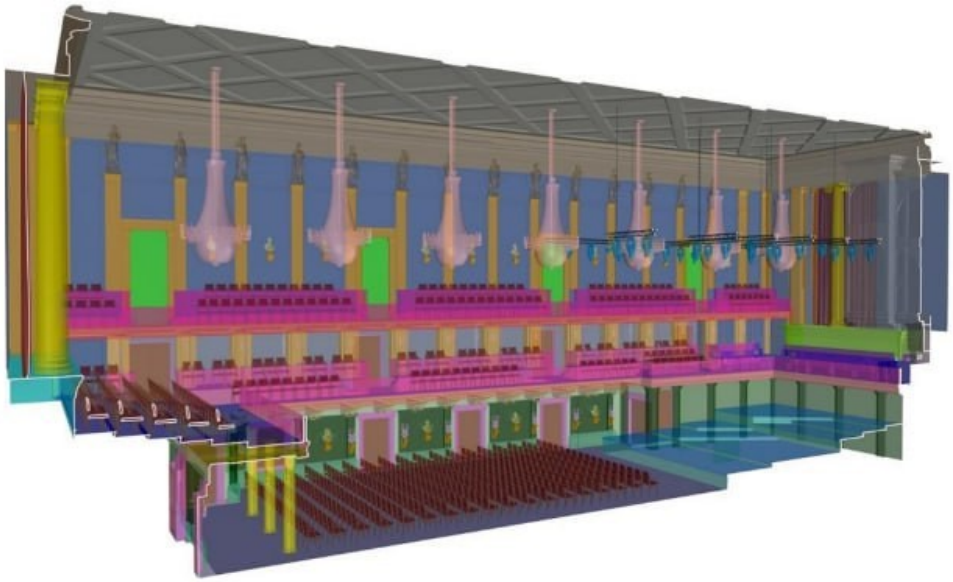


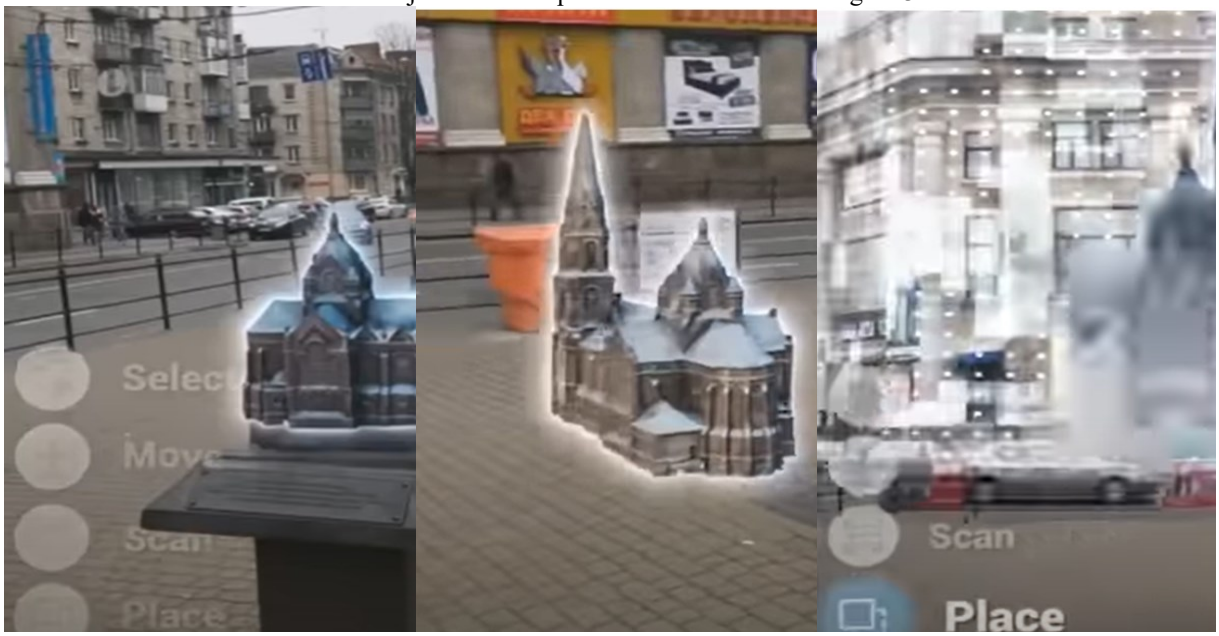
Fig. 2. Example of Case 1 Usage

Case 2: "Augmented Reality for Virtual Tour of Cultural Heritage"

The user opens the application on their mobile device. The app requests permission from the user to access GPS and the camera. The user grants the necessary permissions.

The system determines the user's location and presents a list of nearby cultural heritage objects available for virtual exploration. The user selects one of the objects.

The system loads the 3D model of the chosen object and its historical information. It then displays this model in augmented reality through the mobile device's camera. The user can rotate, zoom in, and zoom out the model and read historical information about the object. An example of this can be seen in Figure 3.



a) b) c)

Fig. 3. Example of Case 2 Usage

Conclusions

The implementation of this information system can open new opportunities for preservation, study, and presentation of cultural heritage. By using advanced technologies such as augmented reality and 3D modeling, the

processes of restoration and conservation of cultural heritage objects can be significantly improved, providing researchers, restorers, and the general public with more opportunities for exploration and evaluation.

Using the proposed system, ordinary users have the ability to virtually visit and explore cultural heritage objects, while restorers can plan and model the restoration processes. All of this has the potential to enhance the understanding and preservation of cultural heritage for future generations.

In future research, the proposed approaches and methods will be implemented to expand the functionality of the information system. This will include developing interactive interfaces for interacting with virtual models of cultural heritage, analyzing data for a deeper understanding of restoration processes and trend detection, as well as integrating cutting-edge information technologies, such as virtual reality and natural language recognition systems, using artificial intelligence. The primary goal is to improve the processes of preserving and studying cultural heritage through the use of modern information technologies.

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