

Application and Challenge of Multi-Source Spatial Data Fusion in Archaeology

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Abstract. The paper explores the application of multi-source spatial data fusion in archaeology and analyzes its future challenges. It shows that multi-source spatial data fusion can help archaeologists discover, analyze and protect archaeological sites and their surroundings more accurately. However, the heterogeneity of data, the complexity of processing and analyzing, and the challenge of interdisciplinary cooperation are still notable issues. The aim of this paper is to investigate the application and role of multi-source spatial data fusion, to explore the challenges it faces, and to propose methods to address these challenges.

Keywords: Archaeology; Cultural Heritage; Heritage Protection.

1. Introduction

Archaeology, the study of human history and cultural heritage, has come to rely on a variety of spatial data sources to reveal and analyze sites, ruins, and their surroundings. This paper focuses on the application of multi-source spatial data fusion in archaeology and analyzes the challenges it will face in the future. The result of this study is that multi-source spatial data fusion enables archaeologists to discover, analyze and protect sites more accurately. However, the heterogeneity of data, the complexity of processing and analysis, and the challenges of interdisciplinary collaboration remain significant. This paper aims to study the application and role of multi-source spatial data fusion, its challenges and how to deal with these challenges.

2. Literature References

With the development of spatial data technologies such as remote sensing, GIS, LiDAR and geological exploration data, archaeologists are able to acquire and analyze a large amount of spatial data. The fusion of these data not only provides new tools for site discovery and conservation, but also drives a deeper understanding of the relationship between ancient societies and the environment. But the fusion of multi-source spatial data also faces many challenges in the application process. This paragraph will discuss the main applications and challenges of multi-source spatial data fusion in archaeology. In terms of the discovery and location of archaeological sites, Menze and Ur have successfully discovered hundreds of ancient ruins in arid regions of Syria using satellite remote sensing technology and geographic information fusion [1]. In the study of ancient environment and land use, the "substitute field method" and "district field method" were popularized during the reign of Emperor Wudi of Han Dynasty in China, which greatly increased the yield per mu [2]. In terms of site protection and management, Parcak and so on used high-resolution satellite images and LiDAR data to successfully assess the damaged environment of several sites in Egypt, and put forward targeted protection recommendations [3]. In terms of data isomers and inconsistencies, Conolly and Lake. M wrote that the inconsistency between historical maps and modern remote sensing data in the coordinate system may lead to bias in data superposition, thus affecting the accuracy of conclusions [4]. In terms of the complexity of data processing and analysis as well as interdisciplinary collaboration and methodological integration, McCoy. m. d proposed that how to effectively deal with large-scale and multi-dimensional spatial data is also a serious challenge. He also wrote that there may be conflicts between research paradigms and analysis methods of different disciplines in

the integration process, which need to be solved through interdisciplinary dialogue and method innovation [5]. Summary of the academic discussion of the Digital Archaeology Professional Committee of the Third Chinese Archaeology Congress. This article reviews recent advances in the field of digital archaeology, including the application of UAV 3D data acquisition and modeling to settlement archaeological research, and the application of GIS and RS to archaeological site investigation and exploration [6]. Multisource and Multitemporal Data Fusion in Remote Sensing: A Comprehensive Review of the State of the Art. This IEEE article provides a comprehensive review of the latest techniques for multi-source and multi-temporal data fusion in remote sensing [7]. Hierarchical Attention and Parallel Filter Fusion Network for Multi-Source Data Classification. This paper proposes a hierarchical attention and parallel filter fusion network for multi-source data classification, which can be used for remote sensing image interpretation in archaeology [8]. The motivation for this article is that data fusion is very important to archaeology, which can improve the accuracy and information of data, help archaeologists more accurately and effectively discover site characteristics, analyze the activity patterns of past civilizations and reconstruct the environment of ancient civilizations. The framework of this paper is to explore the application of multi-source spatial data fusion technology in archaeology, analyze the challenges it faces, and provide references for future archaeological research. This paper analyzes the application status of multi-source spatial data fusion technology, explores its application cases in real archaeology, and discusses the future improvement and possible directions of application of these technologies.

3. The Theoretical Basis And Technical Background

Next is the theoretical basis and technical background, I will be divided into two parts to introduce, the first part is multi-source spatial data, which is divided into remote sensing data, lidar data, gis data and geological exploration data. Remote sensing data refers to the surface image data of satellites and aircraft photos, including but not limited to multi-spectral, panchromatic and infrared, etc., which is mostly used for the detection of surface features. Lidar data refers to the high-resolution three-dimensional terrain data obtained by laser scanning, which has unique advantages in the jungle covered area. gis data refers to the integration of a variety of geospatial data to support spatial analysis, modeling and visualization, and is mostly used for the positioning and analysis of archaeological sites. Geological exploration data, which includes seismic, magnetic, and electrical resistance data, is mostly used to help reveal the archaeological sites below the surface and the surrounding geological features. The second part is the technology and method of multi-source data fusion, data preprocessing technology is divided into data cleaning and standardization and data registration, data cleaning and standardization refers to the processing of noise and outlier in the data, and the unification of spatial resolution and coordinate system of different data sources. Data registration is to ensure that multiple sources of data in the same spatial reference system, over and over again for subsequent comprehensive analysis. The data fusion methods are pixel-based fusion, feature-based fusion and decision-based fusion.

4. The Application Of Multi-source Spatial Data Fusion

Then, it discusses the application of multi-source spatial data fusion. First, it is conducive to the discovery and location of archaeological sites. By combining remote sensing images, topographic data, historical maps and documentation, archaeologists can effectively find potential archaeological sites in a large range of areas that are difficult to be found by traditional archaeological methods. For example, the Maya civilization site detection, the Maya civilization is widely distributed and complex, it is difficult to cover the whole area with traditional archaeological methods, and the use of high-resolution remote sensing image and lidar data, and the use of computers for automated site detection. The accuracy of site discovery has been significantly improved, and a number of new archaeological sites have been identified through data fusion. Second, the ancient environment and land use can be better studied. By integrating different types of spatial data, such as vegetation cover, geological features and hydrological information, archaeologists can reconstruct the ancient environment and

analyze the relationship between the environment and sites, for example, studying the ancient civilization of the Nile River. The Nile Valley is the birthplace of ancient Egyptian civilization. It is of great value to archaeology to study the relationship between the environment and the surrounding environment. By fusing different types of spatial data, such as vegetation cover, geological features and hydrological information, archaeologists can reconstruct the ancient environment and analyze the impact of human activities on the environment, revealing the close relationship between water resources, geological structures and the layout of ancient cities, providing new perspectives for understanding the rise and fall of ancient civilizations. The third is conducive to the protection and management of sites, such as the management of the murals in the Mogao Grottoes of Dunhuang, which are precious marks left by civilization. With the increase of tourists, how to better protect the safety of the murals has become a problem. By combining 3D scanning data, environmental monitoring data and historical images, archaeologists can assess the preservation status of the site and formulate scientific protection measures. Better analysis of the preservation of the frescoes is made, and the integrity of the frescoes is better protected.

5. The Challenges Multi-source Spatial Fusion Faces Nowadays

However, multi-source spatial data fusion also faces many challenges. The first is the problem of data compatibility and consistency. Because the resolution accuracy, time span and spatial reference system of different data sources are different, data compatibility and consistency have become the main obstacles to data fusion. For example, inconsistencies in coordinate systems between historical maps and modern remote sensing data may lead to bias when data are superimposed, thus affecting the accuracy of archaeological conclusions. The way to deal with this problem is to adopt advanced data registration algorithms and standardized processing methods to improve the compatibility and consistency of data and ensure the reliability of fusion results. The second is the complexity of data processing and calculation. Multi-source data fusion involves large-scale data processing, especially high-resolution remote sensing and LiDAR data, which has high computational complexity and long processing time. In addition, how to effectively deal with large-scale and multi-dimensional spatial data is also a serious challenge. The solution is that people can use high-performance computing platforms and distributed computing technology to accelerate the data processing process and optimize the algorithm to reduce the time. The third is the integration of interdisciplinary cooperation and methodology. Multi-source spatial data fusion requires archaeologists to work closely with interdisciplinary experts such as geographic information scientists, remote sensing experts, and computer scientists. While such collaboration contributes to the diversity and depth of research, it can also face communication barriers and methodological inconsistencies. For example, there may be conflicts between research paradigms and analytical methods of different disciplines in the integration process, which need to be resolved through interdisciplinary dialogue and methodological innovation.

All in all, multi-source spatial data fusion technology provides a powerful tool for archaeological research, significantly improving the accuracy and efficiency of site detection, environmental reconstruction and cultural analysis. Although there are multiple technical challenges, they can be overcome with effective strategies and technological innovations to fully realize the potential of multi-source data fusion. As for the future research direction, the first is the integration of emerging technologies, exploring the combination of artificial intelligence, deep learning and multi-source data fusion, so as to develop more intelligent archaeological data analysis tools; The second is real-time data processing and dynamic analysis. People can study how to process and analyze multi-source data in real time, support dynamic monitoring and decision-making, and improve the response speed and flexibility of archaeological research. The third is interdisciplinary cooperation and technological innovation, exploring the application of new methods and technologies in data fusion by promoting the deep integration of archaeology with geographic information science and computer science. With the continuous improvement of data collection technology and computing power, multi-source data fusion will play a greater role in archaeology, providing stronger support for archaeological research and cultural heritage protection.

6. Summary

This thesis explores the application and challenges of multi-source spatial data fusion in archaeology. With the development of spatial data technologies such as remote sensing, GIS, LiDAR, and geological exploration, archaeologists are able to acquire and analyze a large amount of spatial data, which provides new tools for site discovery and preservation and promotes an in-depth understanding of the relationship between ancient societies and their environments. Although multi-source data fusion can improve the accuracy and efficiency of archaeological research, there are still challenges of data compatibility and consistency, complexity of data processing and computation, and interdisciplinary cooperation. In order to address these issues, researchers need to adopt advanced data processing techniques and enhance interdisciplinary communication and cooperation. Looking ahead, the integration of emerging technologies such as artificial intelligence and deep learning, the realization of real-time data processing and dynamic analysis, and the promotion of the deep integration of archaeology with geographic information science and computer science will open up new directions for the application of multi-source data fusion in archaeological research. Overall, multi-source spatial data fusion technology will play an increasingly important role in archaeological research and cultural heritage protection.

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