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Development Trend of Remote Sensing Archaeology Based on Scientific Literature

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Abstract. Remote sensing has been a necessary detection technology in the archaeological field, which has nearly 30 years of history. Based on the SCI paper data, we analysed the development trend of remote sensing archaeology technology. We did a quantitative review of research progress in remote sensing archaeology to explore the number, the related countries, and the institutions of research articles on this topic. We then draw knowledge graphs to explore the historical, current, and further development of the remote sensing archaeology technology using VOSViewer visualization software. These results could help the researchers get an overview of this field quickly and accurately.

Keywords. remote sensing archaeology; bibliometric analysis; knowledge graph; development trends analysis

1. Introduction

Remote sensing archaeological technology (RSAT) began with aviation archaeological technology at the beginning of the 20th century. Since the 1970s, space observation technologies including remote sensing technology, global positioning technology, geographic information system, and virtual reality technology have been developed rapidly. Global satellite remote sensing archaeology has been widely used. RSAT has gradually become an indispensable and commonly-adopted detection method in the field of archaeology [1]. RSAT gets the image data of archaeological sites from different platforms such as space shuttles, satellites, and aircraft using cameras, scanners, radars, and other imaging equipment. RSAT helps the researchers to determine the location, distribution, shape, depth, and other characteristics of the site according to the interrelationship between the manifestations and spectral imaging laws within the scope of the site, the hue, texture, pattern, and space-time distribution laws of the image [2]. It is one of the essential technologies of site exploration, archaeological surveys, ancient landforms, and ancient site restoration.

Bibliometric is one of the important methods for quantitative measurement of discipline fields, which focuses on literature information such as research articles and patents [3]. Using statistical analysis methods to macroscopically reflect important factors such as the time axis of technological development, future trends, and global scientific

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and technological competitiveness in a certain discipline field through intuitive data. In this article, the output of scientific and technological articles in the field of RSAT is objectively analysed by way of principles of bibliometrics and statistics, which show the development status of RSAT and reveal research hotspots. This research aims to provide reference information on the layout of remote-sensing archaeologists.

2. Data Collection and Methods

In this study, the ISI Web of Science (WoS) platform is used as the source of data for bibliometric analysis. It is an authentic platform for global scientists to communicate frontier fields with peers. We chose the Science Citation Index Expanded (SCI-EXPANDED) of WoS Core Collection as our data source for this study. We conducted a Topic Search by searching the combined expression term in the Title, Abstract, and the Author's Keywords fields in the SCI-EXPANDED database on 17 January 2023. The search returned 5771 pieces of research articles.

In this article, the bibliometric method was chosen and the data analysis tools such as VOSViewer, DDA (Derwent Data Analyzer), and Excel were used for data mining and visual panoramic analysis.

3. Quantitative Analysis and Results

3.1 Publication outputs

In the field of RSAT research, the earliest articles first appeared in 1970, and were published in the journal named Photogrammetric Engineering. This article recorded the process of photographing and recording archaeological sites in Turkey, Greece, and Cyprus in detail. The authors used tethered balloons to collect data [4]. It can be seen that the equipment used to collect and analyse data at that time was relatively simple and had low efficiency.

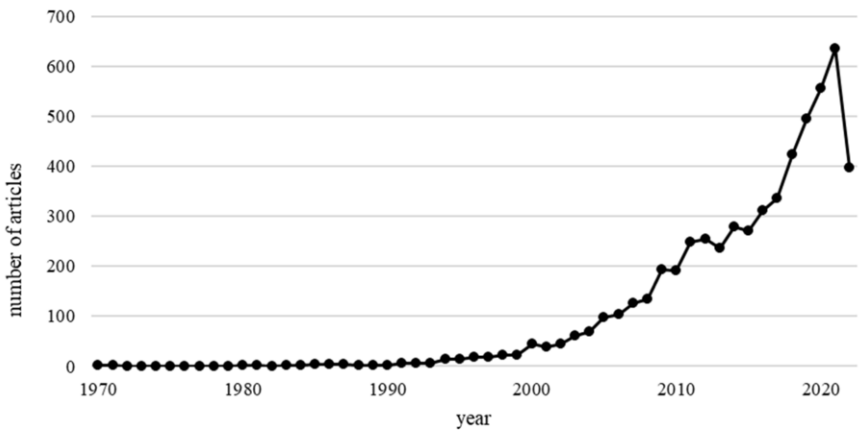

Figure 1. The annual number of articles on Remote Sensing Archaeology

The annual output of RSAT articles is shown in Figure 1. Before 1993, the annual output was sporadic which is less than 8 articles each year. In 1994, the number of articles exceeded 10 and grew slowly. Since 2000, the growth of annual article output presents an obvious rising trend. And in 2006, the number of articles increased from 100 to 104 for the first time. The peak of article output reached 636 in 2021.

3.2 Major Countries and Regions

According to RSAT bibliometric profile, nearly 100 main countries and regions were found in which research was conducted and applied. As shown in Figure 2, the total number of articles published by the top 10 countries accounts for nearly 70%. Italy has the largest number of world heritage sites in the world and attaches great importance to the research and development of archaeology. So the number of Italy's articles in RSAT is far ahead with a number of 1119, ranking first. The top five productive countries were Italy with 1119 papers, the USA with 574, China with 485, Spain with 445, and the UK with 379.

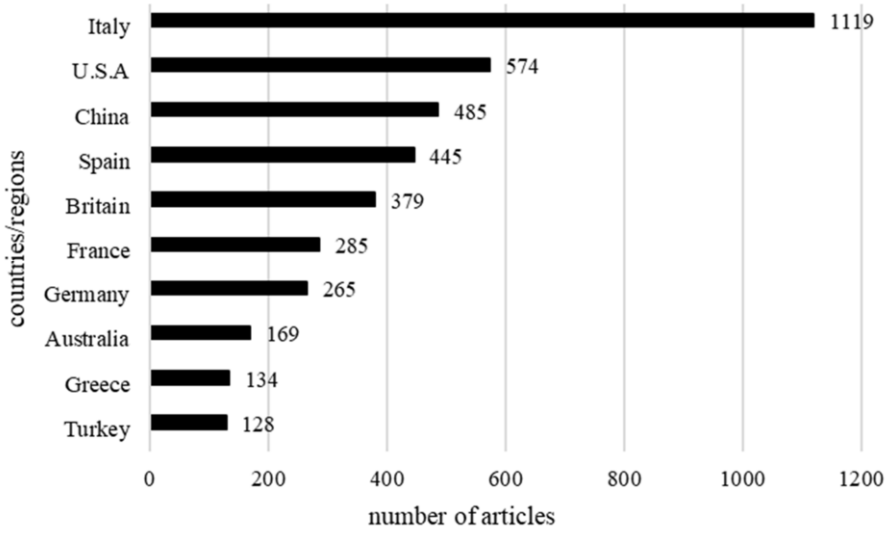

Figure 2. Ranking of Top 10 Countries of Remote Sensing Archaeology

To a certain extent, the citation frequency of articles can reflect the quality of the articles. The higher the citation frequency is, the higher the attention and recognition of researchers will be [5]. So, citations are important for career advancement of researchers. Table 1 shows the top 10 countries ranked according to the total citation frequency of articles. It can be seen that Italy, the USA, and the UK rank top three in terms of the total frequency of citations, among which the frequency of citations per article in the UK is 25.81 times. When analysing the performance of China in the output of articles, the total frequency of citations, and the frequency of citations per article, the total number of articles published in China ranked third, but the citation frequency is only 10.74 times per article. The result indicated that China's highly influential articles in the field of RSAT need to be further improved.

Table 1. Ranking of Top 10 Countries in Total Cited Frequency of Remote Sensing Archaeology

Ranking	Countries/Regions	Total Cited Frequency	Frequency of Citations per Article
1	Italy	21086	18.84
2	the USA	13170	22.94
3	The UK	9783	25.81
4	Spain	7795	17.52
5	Germany	6205	23.42
6	France	6145	21.56
7	Australia	5569	32.95
8	China	5210	10.74
9	Greece	2740	20.45
10	Canada	2652	26.00

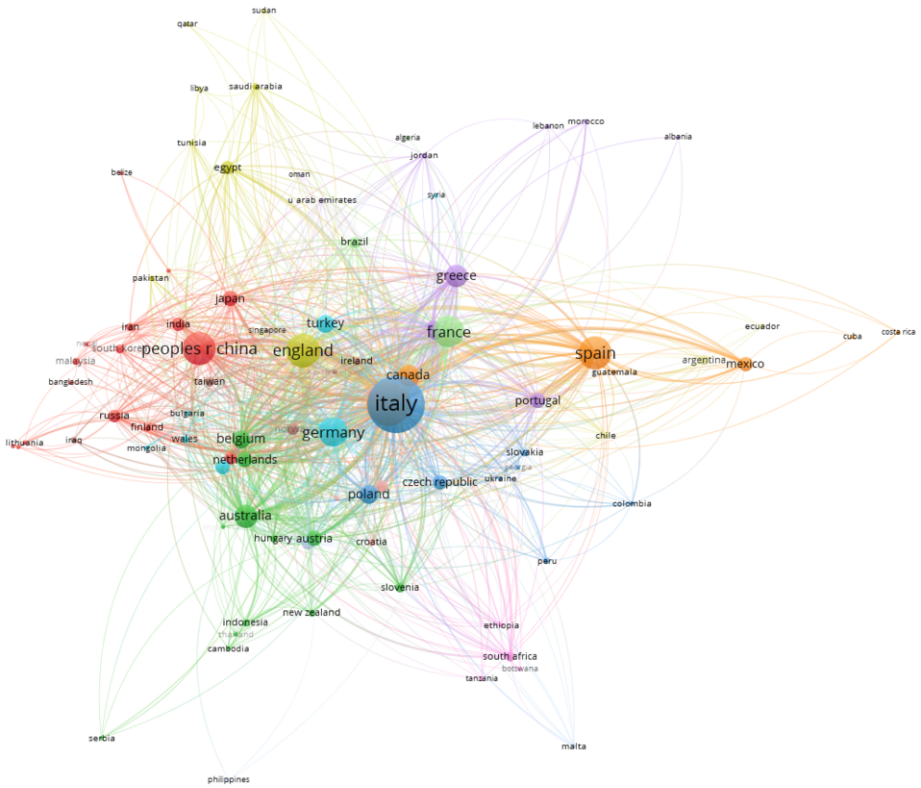

Figure 3. The Cooperation of Countries/Regions of Remote Sensing Archaeology

The cooperation network of an article can visually show the scientific and technological cooperation of countries/regions in some research fields. If two countries / regions collaboratively publish an article, they will be connected with line segments. The thicker the line segments are, the closer the cooperation is. As can be seen in Figure 3, Italy has the most active cooperation in RSAT. Spain, France, Britain, Germany, the USA, Canada, and Belgium are Italy's close partners. The USA cooperates frequently with the UK, Canada, and Australia, and the UK has the largest number of cooperation articles. China has also actively participated in international cooperation, which has

carried out more cooperation with the USA, Australia, Britain, Canada, Germany, and France.

3.3 Major Research Institutions

Table 2 lists the top 15 most common institutions listed in RSAT research. It can be seen that the institutions are mainly concentrated in European, with Italy owning the largest number of research institutions, followed by France and the UK. The number of articles issued by the Italian National Research Council (CNR) is 295, ranked first, far more than other institutions, indicating that this institution has good academic ability.

Table 2. Ranking of Top 15 Institutions of Remote Sensing Archaeology

Ranking	Institutions	Number of articles	Total Cited Frequency	Frequency of Citations per Article
1	Italian National Research Council	295	6692	22.68
2	Chinese Academy of Sciences	157	2310	14.71
3	University of Florence	80	1832	22.90
4	University of California	80	2541	31.76
5	University of Bologna	75	1746	23.28
6	Ghent University	70	1426	20.37
7	University of Pisa	66	1287	19.50
8	University of Cambridge	66	3813	57.77
9	National Autonomous University of Mexico	62	954	15.39
10	Polytechnic University of Milan	62	1421	22.92
11	University of Oxford	62	1764	28.45
12	University of Rome	61	623	10.21
13	University of Milan	60	1051	17.52
14	Spanish National Research Council	59	1892	32.07
15	University of Vigo	55	879	15.98

The Italian National Research Council is composed of several professional archaeological research institutions, such as the Institute of Archeological Heritage-Monuments and Sites (IBAM), Institute for the Conservation and Promotion of Cultural Heritage (ICVBC), the Institute for the Technologies Applied to Cultural Heritage (ITABC), and so on. CNR has become the world's leading institution in the field of RSAT after several decades of exploration and development.

The Chinese Academy of Sciences (CAS) ranks second. The number of articles issued by the Aerospace Information Research Institute (AIR) is most under CAS. AIR was established in 2017, following the approval for the consolidation of three CAS institutes: the Institute of Electronics (IECAS), the Institute of Remote Sensing and Digital Earth (RADI), and the Academy of Opto-Electronics (AOE). The merger is promoting RSAT development. AIR has developed an international S&T cooperation platform, including the International Centre on Space Technologies for Natural and Cultural Heritage (HIST). HIST is the first UNESCO Category 2 Centre dedicated to promoting, testing, and demonstrating the applications of space technologies for the conservation, management, and sustainable development of globally significant natural

and cultural heritage, biosphere reserves, and geoparks. In 2001, the National Joint Laboratory of Remote Sensing Archaeology was established, composed of AIR, East China Normal University, and the National Museum of China. The laboratory aims to further improve China's scientific and technological capabilities in the field of RSAT.

3.4 Visual analysis of the research theme

Keywords usually reflect the topic and research content of the article. By analysing the co-occurrence of keywords, we can quickly understand the research focus and research direction in the field of RSAT. We used VOSViewer to construct a keyword co-occurrence network (Figure 4). A total of 1726 keywords were extracted, among which 186 keywords appeared 10 times or more. In the cluster graph, each circle represents a category of topic words and the size of the circle represents the frequency of the category of topic words. The higher the frequency of occurrence is, the larger the diameter of the circle will be. Colour represents the co-occurrence relationship between the theme words. The closer the colour is, the closer the co-occurrence relationship between theme words is.

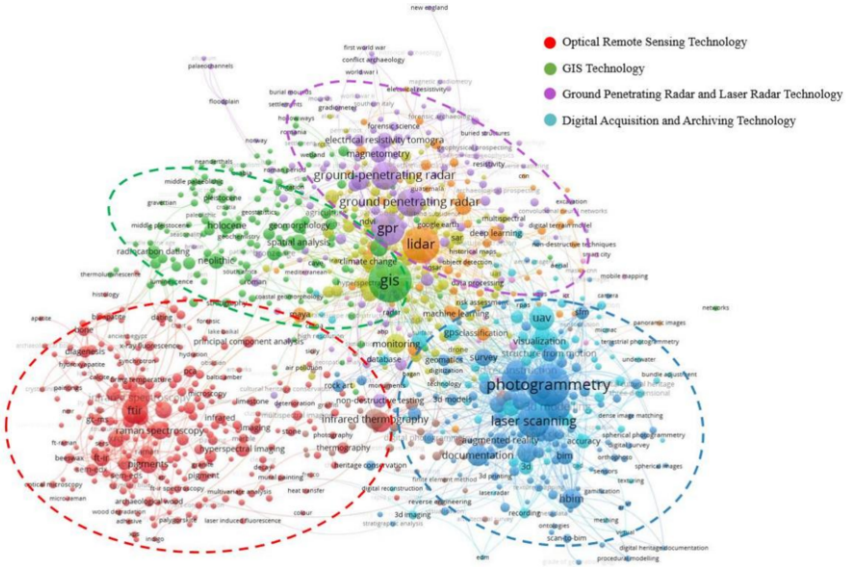

Figure 4. The Co-occurrence Relation of Keywords of Remote Sensing Archaeology

As can be seen from Figure 4, the keywords mainly focus on four topics, namely optical remote sensing technology, geographic information system (GIS) technology, ground penetrating radar and laser radar remote sensing technology, and digital acquisition and archiving technology.

As for the subject of optical remote sensing technology, the research hotspot is detecting the difference in the information of reflection or radiation infrared characteristics of remote scenes using infrared sensors, so the characteristics of site parameters can be accurately determined. Optical remote sensing has been applied earlier in the field of archaeology. Thermal infrared and infrared can be used to identify the surface temperature and vegetation anomalies caused by buried remains. So it is a very common detection method.

As for the subject of GIS technology, the research focuses on the quantitative analysis of the spatial location and environmental geomorphology of sites, and the establishment of prediction models for potential site locations combined with database technology.

As for the subject of ground penetrating radar remote sensing technology, ground penetrating radar is an efficient shallow geophysical detection technology, and most of the research focuses on non-destructive detection of the structural geometry and characteristics of buried sites. In the meantime, laser radar remote sensing technology is a combination of laser technology and photoelectric detection technology. Most of the research focuses on the acquisition of three-dimensional terrain information of archaeological targets in the forest, so as to provide important basic data supporting the discovery of ancient sites and the analysis of the road and water system pattern of the ancient city.

As for the subject of digital acquisition and archiving technology, the application of digital technology to acquisition and archiving is the research hotspot. Digital acquisition technology mainly focuses on photogrammetry technology (aerospace, ground proximity), airborne laser radar technology, and ground laser scanning technology. High-precision 3D modelling and texture mapping have received attention from scientists via the use of ground laser scanning technology to quickly obtain 3D coordinate data of archaeological targets and surrounding scenes. And archive technology mainly focuses on digital archiving.

4. Conclusion

Based on the bibliometric method and a visual grid analysis built with VOSviewer software, we discussed trends emerging in SCI articles on global remote sensing archaeology. The overall trend of RSAT articles is increasing. Italy is the dominant country in this field and has considerable influence. And the total numbers of articles from the USA, China, Spain, and the UK are also large. As for China, although there are many articles, the citation frequency is low which means the influence is not significant. So it is necessary to publish high-impact articles. In terms of the distribution of research institutions, it can be seen that the institutions are mainly concentrated in Europe, with Italy owning the largest quantity of research institutions, followed by France and the UK. Chinese Academy of Sciences has a strong research capacity in RSAT, but the performance of universities is not significant. In the future, it is suggested that China should further strengthen the construction of RSAT in universities and research institutes, and cultivate more professional scientific researchers.

The progress of research in the field of RSAT is explored through a visual analysis of the literature using a bibliometric approach. We find that the main areas of knowledge in the field of RSAT research are optical remote sensing technology, geographic information system (GIS) technology, ground penetrating radar and laser radar remote sensing technology, and digital acquisition and archiving technology. In terms of discipline development, the interdisciplinary nature of remote sensing archaeology is becoming more and more prominent, showing a trend of integration of geophysics, Internet of Things, virtual reality, and high-performance computing technology. With the arrival of the global big data era, the technological convergence of big data and RSAT technology has attracted widespread attention and become a potential hotspot in

poliomyelitis research. This study is helpful for identifying research hotspots and providing directions for future research on RSAT.

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