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A KNOWLEDGE MAPPING ANALYSIS OF DIGITAL PHOTOGRAMMETRY RESEARCH USING CITESPACE

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ABSTRACT

In order to clearly understand the current status and application trends of digital photogrammetry domestic and overseas research, taking the core journals of Web of Science (WoS) as the data source, using bibliometric methods and CiteSpace to carry out statistical analysis of the relevant literature of digital photogrammetry research. The results show that since 2011, the research literature on digital photogrammetry has shown a steady growth year by year. Digital photogrammetry is most closely related to the three disciplines of geology, earth science integration, and physical geography; countries such as the United States, the United Kingdom, Italy, and China publish the most papers, and these countries have strong research capabilities. Lane S.N. and Chandler J.H. have been shared with a high number of citations, who are representative scholars in this field; Digital photogrammetry contains multiple research directions. This article studies the research frontier and trend analysis of digital photogrammetry through keyword co-occurrence analysis and mutation detection analysis.

KEYWORDS

Web of Science, WoS, Knowledge mapping, CiteSpace, Digital photogrammetry, Document metrology, Visual analysis

INTRODUCTION

Photogrammetry is a field of geodesy, and it originated with very similar approaches from the pioneering works of Laussedat in France [1] and Meydenbauer in Germany [2] about 10 years apart, i.e. around 1860 and 1870, respectively [3]. Laussedat was the first to use photographic images for topographic surveys as early as 1861 [1]. In 1867, Meydenbauer used his photogrammetric cameras to record metric images from the town church and also a sector of the terrain for topographic purposes [4].

Digital photogrammetry is based on the basic principles of digital imaging and photogrammetry. It uses computer technology, digital image processing, image matching, pattern recognition and other multidisciplinary theories and methods to extract the geometric and physical information of the subject digitally expressed [5]. With the emergence of new sensors, digital photogrammetry has been further developed, such as post assisted aerial triangulation, information extraction combined with lidar images, etc. Digital photogrammetry has the potential to solve many current problems more effectively, and it will be further developed. Therefore, it is necessary to clearly understand the research status of digital photogrammetry at home and abroad, grasp the research trends of digital photogrammetry and study the development of digital photogrammetry.

From the perspective of visualization, this paper uses the method of generating knowledge map to intuitively display the research status and hot spots in the field of digital photogrammetry in recent years, in order to help scholars grasp and analyse the development trend of this discipline more accurately, and provide scientific reference for subsequent research.

DATA AND METHODS

This section should describe in detail the study material, procedures and methods used.

Data sources

Taking the web of science core collection database as the data source, the period is limited from 1900 to December 2020, the language is limited to English, and the literature type is limited to article and review After that, 939 related literatures were obtained.

research method

CiteSpace developed by Professor Chen Chaomei of Drexel University, is one of the most characteristic and influential information visualization analysis software developed under the background of scientometrics, data and information visualization [6]. It can not only provide the mining of citation space, but also provide the co-occurrence analysis function among other knowledge units, such as the cooperation among authors, institutions regions and countries [7]. In this paper, CiteSpace v.5.7.r2 (64 bit) is used as a visualization tool to draw a series of related knowledge maps and analyze the research status and trends of digital photogrammetry.

RESULTS AND ANALYSIS

Time series analysis of literature output

As shown in Figure 1, the overall trend of literature in the field of digital photogrammetry retrieved by WoS is gradually increasing. Searchable literature in WoS was first published in 1991 and reached the peak of literature growth rate in 1995. Because of the influence of covid pandemic in 2020, the annual number of published papers reached a maximum of 87 in 2019. From 1991 to 2000, 89 literatures were published in the field of digital photogrammetry, accounting for only 9% of the total. From 2001 to 2010, 272 literatures were published, accounting for 29% of the total. From 2011 to 2020, 577 literature was published in this field, accounting for 62% of the total, which is 6.5 times the published literature in 1991-2000. Especially since 2011, the number of related research literature has been steadily increasing. The rise of literatures numbers is accompanied with the rise of journal numbers, as Figure 2 shows. The number of people continues to increase, except for the influence of the covid pandemic in 2020.

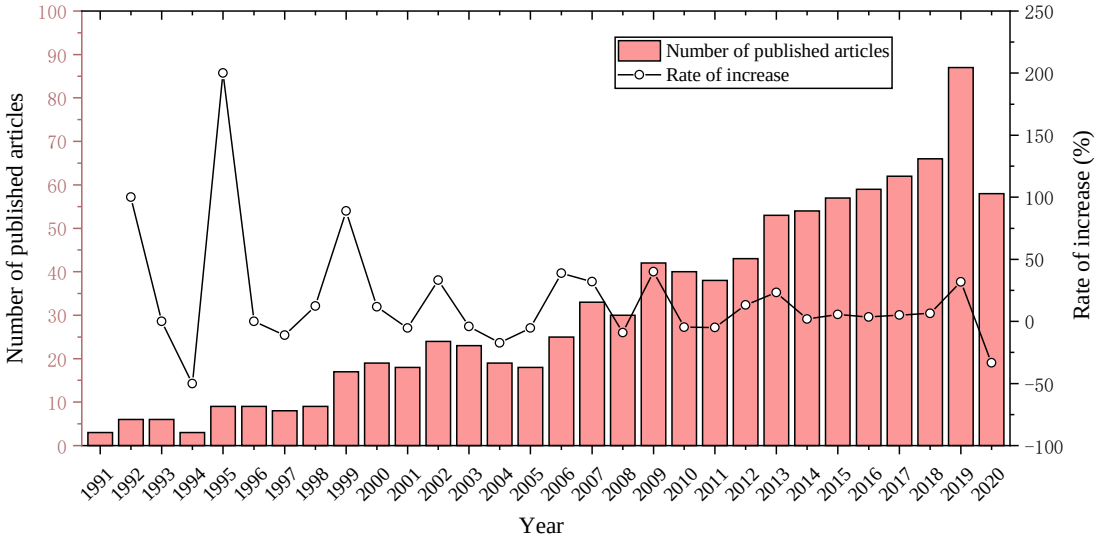

Fig. 1 – Number and growth trend of published literature year by year

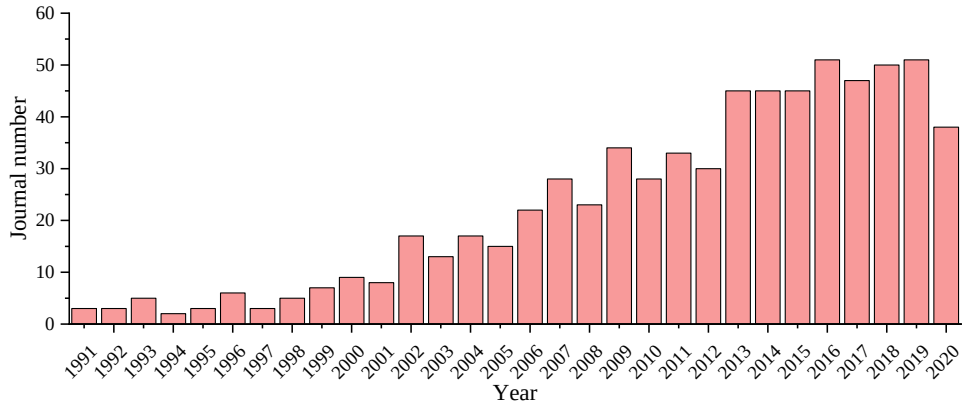

Fig. 2 – Number of journals in which articles are published

Main publishing subjects

The node selects the category, and uses CiteSpace to analyze 939 literatures, finally obtains 136 subject categories. The top 10 discipline categories and the relative number are shown in Figure 3, respectively. It can be seen that the most published papers in digital photogrammetry are geology, geoscience synthesis and physical geography.

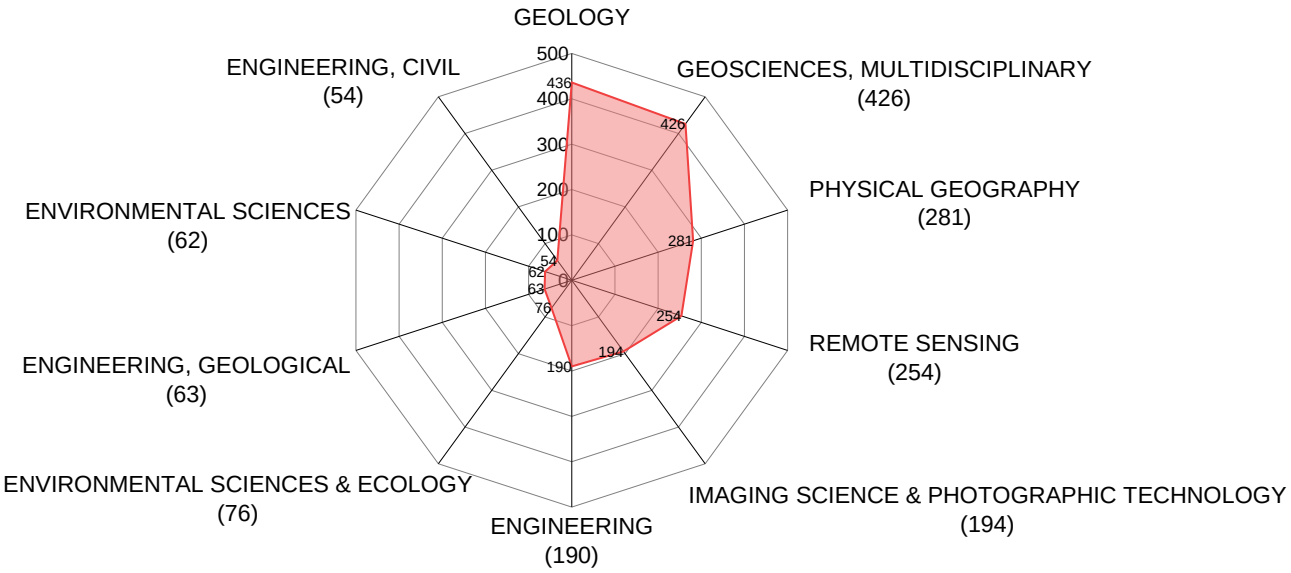

Fig. 3 – Top 10 subjects of digital photogrammetry

Main published journals and co-cited journals

By using the literature analysis function of NoteExpress, the obtained data are shown in Table 1.

Tab. 1 - Top 10 journals with the largest number of literatures on Digital Photogrammetry

Journals	Article number	Countrys
PHOTOGRAMMETRIC RECORD	77	UK
EARTH SURFACE PROCESSES AND LANDFORMS	58	UK
ISPRS JOURNAL OF PHOTOGRAMMETRY AND REMOTE SENSING	40	NED
REMOTE SENSING	36	SUI
PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING	35	USA
GEOMORPHOLOGY	27	NED
INTERNATIONAL JOURNAL OF REMOTE SENSING	21	UK
JOURNAL OF CULTURAL HERITAGE	17	FRA
ENGINEERING GEOLOGY	16	SUI
WATER RESOURCES RESEARCH	9	USA

It can be seen that the high-quality literatures published in the field of digital photogrammetry mainly focus on the Photogrammetric Record, Earth Surface Processes and Landforms and ISPRS Journal of Photography and Remote Sensing. These journals are mainly concentrated in the United States, the United Kingdom, the Netherlands, Switzerland and France. The cited journal node is selected, and CiteSpace is used to analyze the journal co-citation, and the obtained data shown in Figure 4 and Table 2

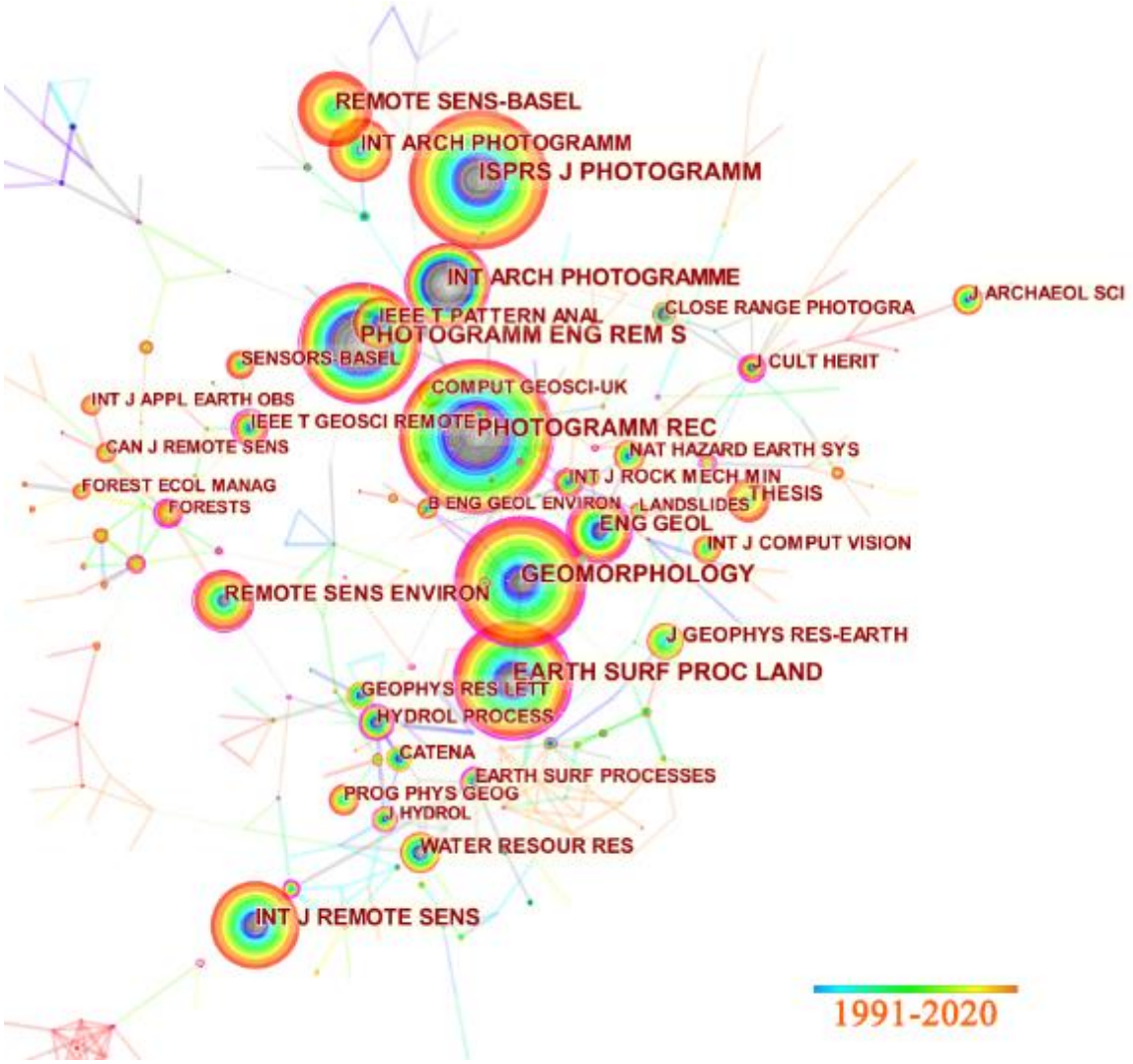

Fig. 4 – Knowledge map of co-cited journals

Tab. 2 - The top 10 journals cited most frequently in digital photogrammetry research

Journals	Article number	Countrys
PHOTOGRAMMETRIC RECORD	353	UK
ISPRS JOURNAL OF PHOTOGRAMMETRY AND REMOTE SENSING	337	UK
GEOMORPHOLOGY	294	NED
PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING	289	USA
EARTH SURFACE PROCESSES AND LANDFORMS	263	UK
INTERNATIONAL JOURNAL OF REMOTE SENSING	213	UK
INTERNATIONAL ARCHIVES OF PHOTOGRAMMETRY AND REMOTE SENSING	205	GER
REMOTE SENS-BASEL	170	SUI
ENGINEERING GEOLOGY	150	SUI

It can be seen that the journals with the largest number of citations are mainly concentrated in the United Kingdom, the United States, Switzerland and the Netherlands. To sum up, journals with certain international influence in the field of digital photogrammetry are mainly in the United States, the United Kingdom, the Netherlands and Switzerland.

Main sending countries

To obtain the co-occurrence network by CiteSpace, Taiwan, people R China are merged into China, Scotland, England, UK, North Ireland and Walls are merged into the UK, the result as shown in Figure 5. Each node represents a country, the size of the node represents the frequency of occurrence. The larger the node represents the higher the frequency of occurrence, that is, the more published literature. The connection between nodes represents the co-occurrence strength, the coarseness of the connection is the closer the cooperative relationship is, otherwise, the more distant the connection is. The larger the diameter of the node is, the greater the influence of the node in this field. It can be seen from Figure 4 that the USA, the UK, China, Italy, Germany and Switzerland have a certain influence in the field of digital photogrammetry.

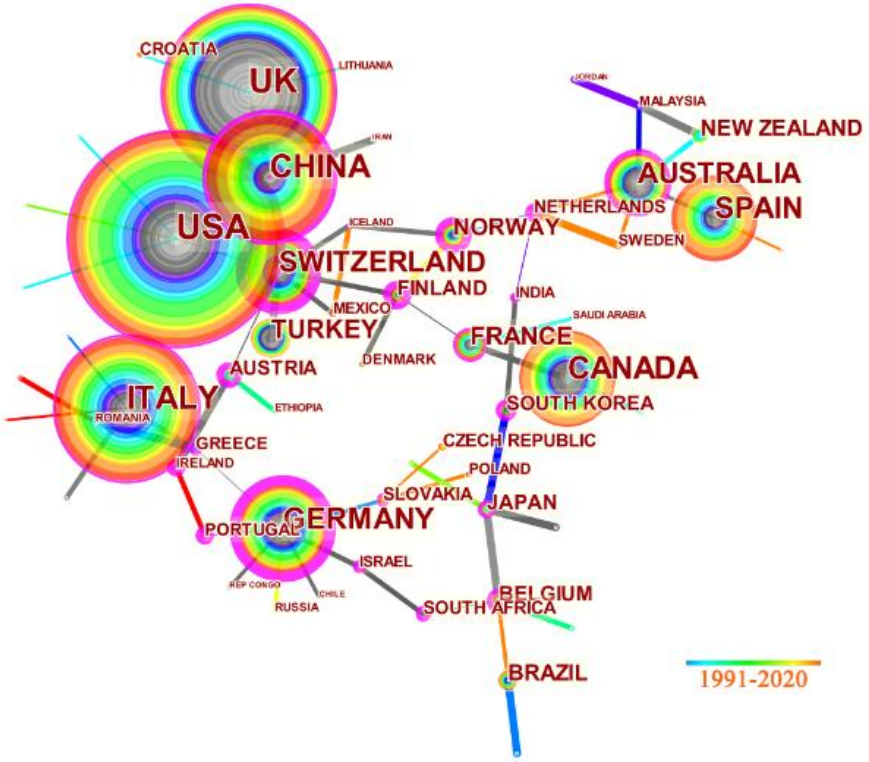

Fig. 5 – National knowledge map of digital photogrammetry research

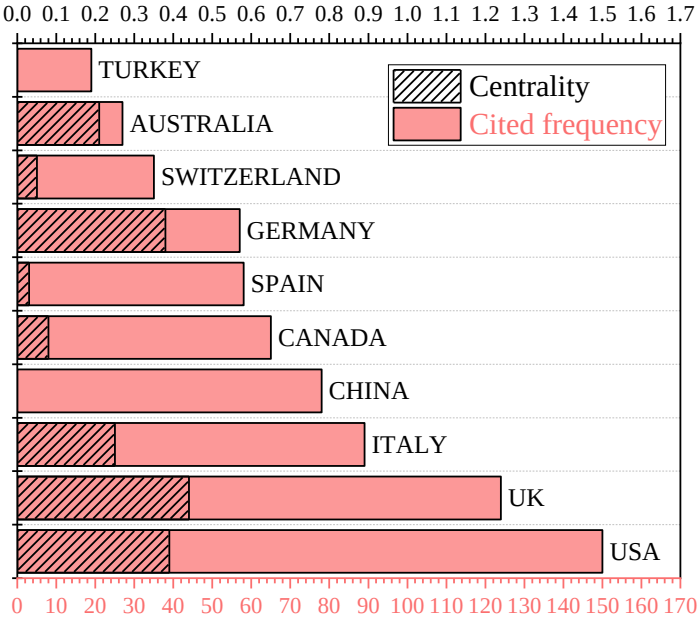

Fig. 6 – Distribution of major countries in Digital Photogrammetry

As shown in Figure 6, scholars who published digital photogrammetry literature mainly concentrated in the United States (153 articles), the United Kingdom (128 articles), Italy (102 articles), China (93 articles) and Canada (77 articles). The most central countries are the United Kingdom (0.44), the United States (0.39), Spain (0.38), Italy (0.25) and Australia (0.21). It can be seen that in the field of digital photogrammetry, scholars from the United States, the United Kingdom and Italy have published many papers, and the literature has a certain international influence. Although Chinese and Canadian scholars have certain advantages in the number of publications in the field of digital photogrammetry, the international influence of the literature is weak on the whole. In contrast, Australian scholars have published in the field of digital photogrammetry Although the literature is not dominant in quantity, it has a strong international influence on the whole.

Major co-authors

By using cited author analysis function in CiteSpace, the co-citation knowledge map of co-cited authors is obtained, as shown in Figure 7. The top 10 co-cited authors ranking, as shown in Table 3 The results showed that Lane S.N. (Institute of Earth Surface Dynamics, University of Lausanne, Switzerland) and Chandler J.H. (Former Professor of Geomatics, Loughborough University, UK) were the most frequently cited authors with 150 and 147 times respectively, which were in the first echelon; Westby M.J. and Remondino F. were more than 80 co-cited, which were in the second echelon; James M.R., Butler J.B., Brasington J., Sturzenegger M. and Kraus K. has been cited more than 70 times, which is in the third echelon. These authors form the core author group of digital photogrammetry research, and have made great contributions to the related research of digital photogrammetry. Further study of the literature shows that the core authors' research mainly focuses on Photogrammetry or remote sensing technology such as digital photogrammetry, lidar, high-resolution satellite remote sensing [8]. In order to carry out geomorphic change research [9] and Hydraulic Research [10,11] With the development of computer vision technology, some scholars combine it with photogrammetry technology, carry out image matching through SFM [12] or MVS (Multiview-stereo) and other algorithms [13,14], and establish three-dimensional models of geomorphology and historical monuments [15] such as river channels [16]. Some scholars use digital photogrammetry for slope monitoring, [17,18] and deformation monitoring of common structures [19,20,21].

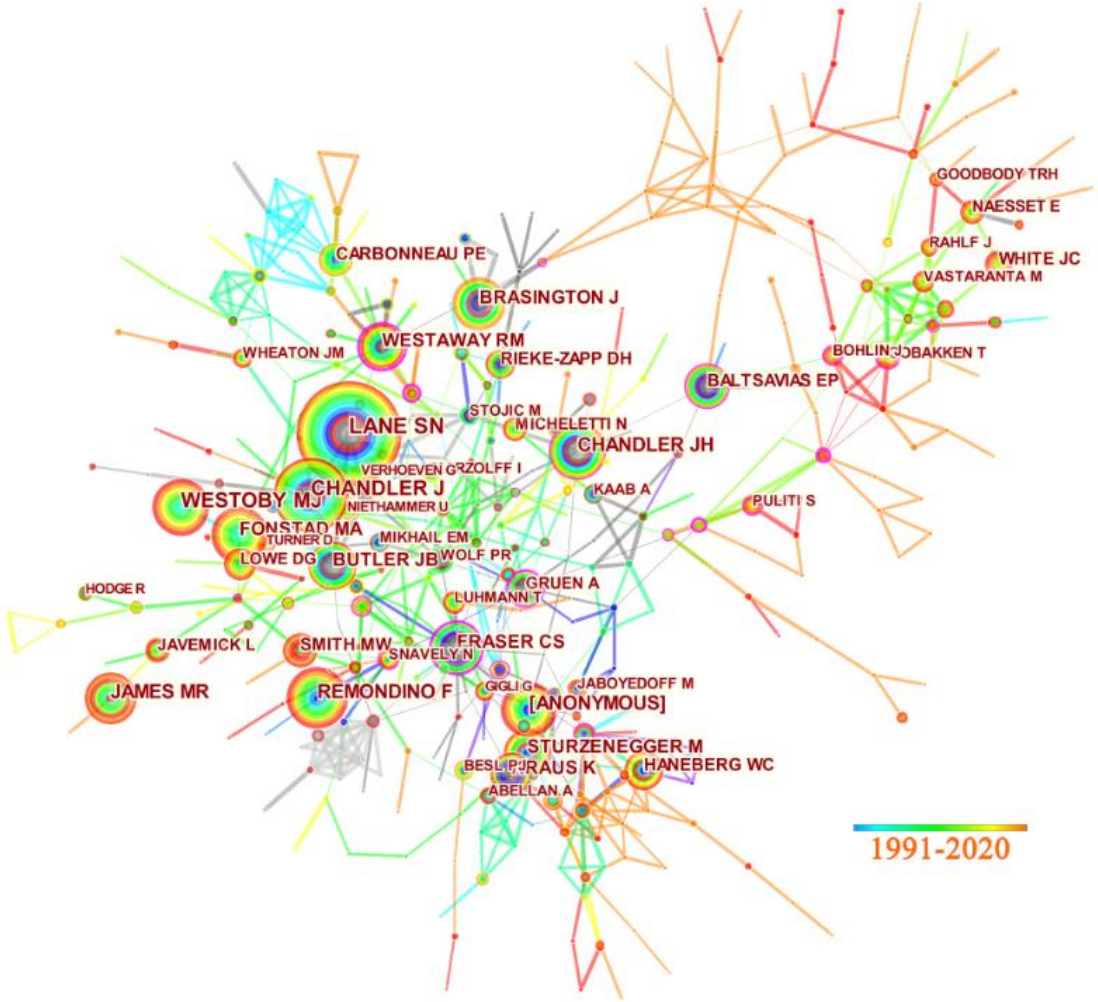

Fig. 7 – Co-citation and co-visualization of digital photogrammetry

Tab. 3: Top 10 co-cited authors of digital photogrammetry

Co-citation times	Authors
150	Lane S.N.
147	Chandler J.H.
96	Westoby M.J.
83	Remondino F.
76	James M.R.
75	Butler J.B.
73	Brasington J.
73	Sturzenegger M.
71	Kraus K.
69	Fraser C.S.

Keyword analysis

The keyword map is more conducive to scholars' analysis of research hotspots and the evolution of hot spots [23]. The relevant research papers on digital photogrammetry from 1991 to 2020 were collected, and the keyword statistics of retrieved literatures were conducted by CiteSpace. The top 20 high-frequency keywords of digital photogrammetry research were obtained as shown in Table 4

Tab. 4: Top 20 high-frequency keywords of digital photogrammetry research

Rank	Freq	Keywords	Rank	Freq	Keywords
1	327	digital photogrammetry	11	45	laser scanner
2	196	photogrammetry	12	45	point cloud
3	85	accuracy	13	41	topography
4	81	structure from motion	14	34	surface
5	78	lidar	15	31	landslide
6	68	unmanned aerial vehicle	16	26	remote sensing
7	63	model	17	25	documentation
8	60	digital elevation model	18	24	low cost
9	50	system	19	22	morphology
10	48	erosion	20	22	reconstruction

In order to further understand the relationship and closeness of high-frequency keywords, the co-occurrence analysis of keywords and the research frontier trend analysis were carried out.

Co-occurrence analysis of key words

Keyword co-occurrence analysis is to use mathematical algorithms and econometric methods to conduct data statistics and cluster analysis on literature keywords and subject words, to obtain hot topics and frontier trends in a certain field. Through the visualization function of CiteSpace, the co-occurrence knowledge map of high-frequency keywords in digital photogrammetry is generated (Figure 8). It can be seen that digital photogrammetry and SFM are the two centres of the whole network and they occupy the core position. Around these two cores, there are two closely related groups:

Digital photogrammetry and unmanned aerial vehicle (UAV) are formed the group of high-frequency keywords, such as vehicle, erosion, digital elevation model and landslide, involves geology, geomorphology and earth science. It reflects that digital photogrammetry has some applications in the field of geological geomorphology. Topographic change detection is a powerful tool in geomorphology, which can link the rates, patterns, processes and impacts of erosion and deposition. It is often applied to the study of processes such as river dynamics [24]. Airborne and land-based lidar is a standard tool for quantifying geomorphic changes. Although the data quality is high, it has disadvantages of poor current situation, high cost and inconvenient scanning. With the development of Unmanned Aerial System (UAS) technology, photogrammetry technology based on UAS, with its superior convenience and economy, is increasingly used to generate high-resolution topographic maps for the study of topographic changes [25].

The group is composed of SFM, photogrammetry, topography, low cost, terrestrial laser scanning and other core high-frequency keywords, involving geomorphology, computer vision and surveying and mapping. The SFM algorithm supports the generation of topographic maps from randomly oriented and distributed photos from uncalibrated cameras [26]. With the rapid development of computer vision, there is a method that can calculate the internal and external azimuth angle elements of a camera by taking a group of photos. These data can be used to measure

the same name image points in overlapping photos and generate 3D point clouds [16]. Lidar can carry out high-precision and high-resolution measurement with high accuracy [27]. However, although the data quality is reliable, there are obvious defects in the research of lidar change detection: the land-based lidar instrument is expensive, in many cases, due to the limited field of vision, it is necessary to scan from multiple locations to obtain sufficient coverage; airborne lidar measurement is not economical, and frequent measurement is usually not feasible, which leads to the poor reality, unable to respond quickly to sudden geomorphic events. The SFM algorithm based on digital photogrammetry can quickly generate digital elevation model, and it is easy to operate and has a high degree of automation. However, the accuracy of the SFM algorithm depends on image resolution. It is also related to the image quality, image distortion, vegetation and surface characteristics, as well as the number, distribution and accuracy of ground control points [28]. How to improve the accuracy and stability of the SFM algorithm is still a hot issue.

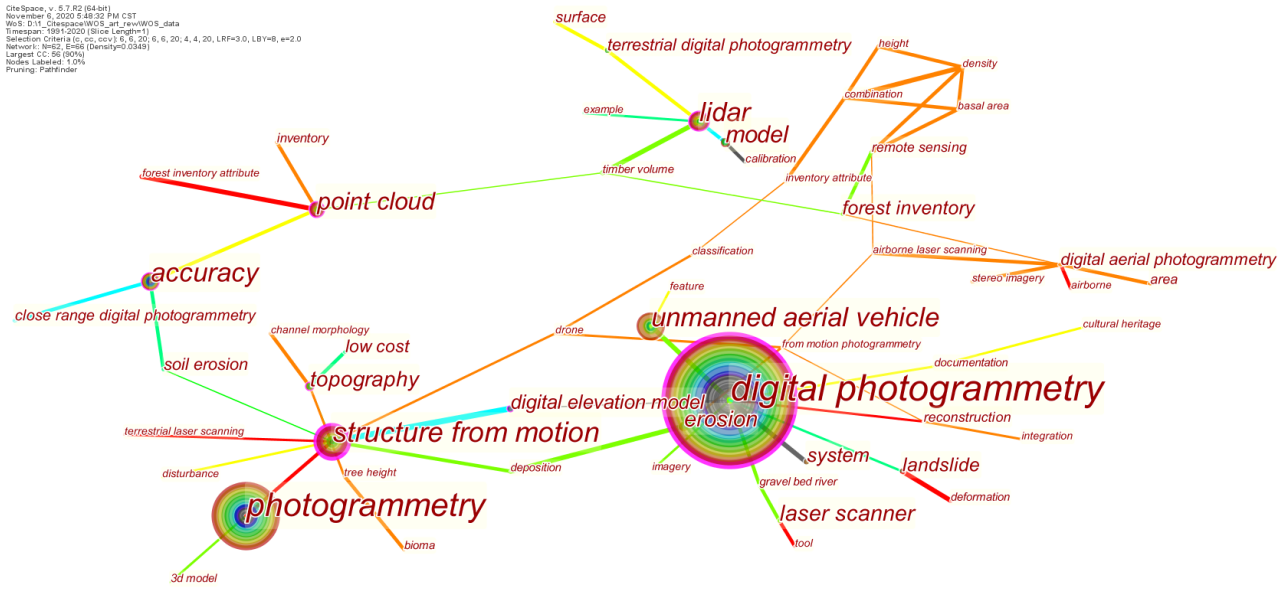

Fig. 8 – Visualization knowledge map of key words co-occurrence in Digital Photogrammetry

Research frontier and trend analysis

The research of digital photogrammetry is a process of gradual evolution. According to the co-occurrence analysis of keywords, it is found that the research content of digital photogrammetry is still expanding. In order to further study and determine the research hotspots of digital photogrammetry, the mutation detection analysis method in CiteSpace is used to obtain the co-occurrence network mutation words of key words in digital photogrammetry (Figure 9) From 1999 to 2010, the mutation intensity of DEM and accuracy are 6.3588 and 6.55 respectively, and "accuracy" refers to the accuracy of DEM. It shows that the research in this period mainly focused on obtaining the original data digital surface model for establishing digital elevation model through digital photogrammetry, and the accuracy of the established digital elevation model was studied in depth. As one of the "4D" products, digital elevation model, its most valuable data source is aerial photogrammetry, which belongs to the category of digital photogrammetry. Through aerial photogrammetry, a large area of original data of DEM can be obtained, to meet the requirements of data current situation [29]. In this period, there were also three-dimensional digital photogrammetry, anthropometry and reliability, which indicated that scholars had realized the advantages of non-contact measurement of digital photogrammetry, and carried out application research on anthropometry combined with three-dimensional digital photogrammetry technology. The mutation time of "anthropometry" lasted from 2003 to 2012, indicating that digital photogrammetry technology had a period of research boom in the field of anthropometry in the early 20th century, and the main researchers were Seth M. Weinberg [30] and Thomas J.J. Maal [31].

From 2011 to 2016, the research focused on rockfall, soil erosion and river accumulation. Kristen L. cook used the images collected by UAV equipped with digital cameras to study the geomorphic changes caused by the spring monsoon in the middle of the Da'an River Canyon in Western Taiwan Province through the SFM algorithm. The experiments show that the accuracy of the SFM point clouds largely depend on the surface characteristics of the measured objects [32]. Baptiste Marteau et al. Applied the SFM algorithm to the field of river restoration, and the experiments show that the digital elevation model generated by the SFM technology can easily determine the geomorphic changes of the river channel over time, and evaluate the spatial changes of erosion and concentration [8]. It can be seen that digital photogrammetry was widely used in geomorphology during this period.

From 2017 to 2020, the mutation intensity of forest inventory, motion recovery structure and unmanned aerial vehicle (UAV) were 6.5264, 13.4714 and 14.071, respectively, which indicated that the main research objects of digital photogrammetry in this stage were forest inventory, movement recovery structure and UAV. Forest resources survey is an important field of applied statistics, involving measurement, tree measurement, remote sensing, data processing and other technologies and methods, and is the only technical means to obtain forest resource information needed for decision-making at different forestry levels [33]. The emergence and rapid development of photogrammetry provide an economical and effective technical means for forest resource inventory. Compared with the traditional measurement methods, photogrammetry can be carried out simultaneously in a large range, which is not limited by the ground visibility conditions, and the measurement cost is relatively low. Especially in recent years, with the development of computer vision theory and efficient automatic feature matching algorithm, SFM 3D reconstruction technology is introduced into photogrammetry, which greatly improves the degree of automation of photogrammetry. The SFM method can automatically solve the position and pose of the camera and the three-dimensional spatial coordinates of the object by matching the same name features from the multi-view photos, which greatly improves the automation of photogrammetry. In addition, with the rapid development of low altitude remote sensing platforms such as small UAVs, they have been widely used in photogrammetry. Compared with the traditional satellite remote sensing platform and aviation platform, they have high data acquisition efficiency, flexible and fast operation mode and low cost. At the same time, because of their flying distance, large-scale and high-precision images can be obtained. The wide application of these low altitude platforms greatly improves the accuracy and efficiency of photogrammetry and greatly reduces the operation cost. At present, photogrammetry has been applied in many fields because of its advantages of low cost and high precision. The mutation intensity of digital aerial photogrammetry, lidar and tree height was high in this period, which reflected the main research means and research objectives in this period.

Keywords	Strength	Begin	End	1991 - 2020
digital elevation model	6.3588	1999	2003	
morphology	5.2483	2003	2012	
digital photogrammetry	7.5263	2004	2008	
Anthropometry accuracy	3.8602	2009	2013	
accuracy	6.55	2009	2011	
laser scanner	4.3891	2009	2013	
precision	4.2901	2010	2011	
reliability	5.522	2010	2012	
digital 3 dimensional photogrammetry	6.2951	2010	2013	
Rockfall	3.9906	2011	2015	
terrestrial digital photogrammetry	5.0144	2011	2015	
soil erosion	6.3706	2013	2017	
Close-range digital photogrammetry	4.2097	2014	2016	
point cloud	8.8161	2016	2020	
deposition	4.1243	2016	2018	
forest inventory	6.5264	2017	2020	
SfM	13.4714	2017	2020	
unmanned aerial vehicle	14.071	2017	2020	
Digital Aerial Photogrammetry	5.2911	2018	2020	
Lidar	4.1258	2018	2020	
Tree height	3.4451	2019	2020	

Fig. 9 – 21 mutation words in the field of digital photogrammetry from 1991 to 2020

CONCLUSION

This paper takes 939 papers about digital photogrammetry in the core database of web of science from 1991 to 2020 as the research object. With the help of the bibliometric method and information visualization analysis software CiteSpace, this paper studies the current situation and trend of digital photogrammetry research, and draws the following conclusions:

Since 2011, the number of research literatures published in the field of digital photogrammetry has increased steadily, but in 2020, the number of published literatures dropped.

Lane S.N. and Chandler J.H. have been cited for the most times. Together with Westby M.J., Remondino F. and other scholars, Lane S.N. and Chandler J.H. are the core authors in the field of digital photogrammetry and they have made certain contributions to the research of digital photogrammetry.

The United Kingdom, the United States and Italy have a certain international influence in the field of digital photogrammetry and are in an important position. At the same time, the academic journals that collect high-quality documents in the field of digital photogrammetry are mainly concentrated in the United States, the United Kingdom, the Netherlands, Switzerland and other countries. In the field of digital photogrammetry, the number of papers published in China ranks first in the world, with strong scientific research strength, however on the whole, the international influence of literature is weak.

From the co-occurrence analysis of key words and the trend analysis of research frontier, it can be seen that the application research of digital photogrammetry in the forestry field and the combination with computer vision and lidar technology have attracted the attention of scholars.

DISCUSSION

Knowledge map analysis visualizes and simplifies the development of digital photogrammetry. Because all the results presented in this article are based on the results retrieved on WoS at one point in time, this article has the following predictable shortcomings:

1. The papers retrieved by WoS are not invariable, and not all the papers retrieved by WoS are of high research value. However, in the section of "Time Series Analysis of Literature Output", we assume that all retrieved literature is regarded as equally important.

2. Due to high publishing costs and possible corporate or institutional competition, some papers need to be analyzed, but we cannot obtain them through WoS, so we have not analyzed them. In order to improve the reliability of data and results, it is recommended to further increase data sources and further filter the data.

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