Journal of Theoretical and Applied Information Technology
31st March 2024. Vol.102. No 6

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

CHARTING NEW FRONTIERS: ASSESSING INFORMATION TECHNOLOGY'S ROLE IN THE EVOLUTION OF IMAGE ENHANCEMENT – A BIBLIOMETRIC APPROACH

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ABSTRACT

Image enhancement techniques hold a crucial role within the realm of image processing. The primary aim of these methods is to enhance the visual appeal of images, making them more suitable for subsequent processing or human interpretation. This research investigates the bibliometric analysis of image enhancement methods, providing a comprehensive perspective of the research landscape in this domain using VOSviewer and biblioshiny. Through a comprehensive review of a substantial body of publications, we include the most prominent authors, institutions, and countries driving advancements in the field of image processing. Additionally, the paper highlights the key challenges and recent developments in image enhancement. This study underscores the collaborative networks among researchers and the extensive array of investigations related to image enhancement. The insights from this study offer practitioners, decision-makers, and academics valuable information that guides them toward influential areas and potential strategies for enhancing images in the future. Various methodologies for image enhancement across different domains are explored, which is crucial for image analysis and recognition. This study uniquely underscores the transformative impact of Information Technology in refining image enhancement methods, contributing to both computational efficiency and enhanced interpretability. The revelation of untapped collaborative networks and innovative methodologies, as presented in this research, marks a significant leap in harnessing Information Technology for future breakthroughs in image processing.
Keywords: *Image Enhancement Method, Bibliometric Analysis, VOSviewer, Biblioshiny.*

1. INTRODUCTION

Image enhancement involves a set of operations with the purpose of modifying digital images to enhance quality and information content prior to display or further analysis for the extraction of quantitative data. The primary objective of image enhancement techniques is to make images more visually appealing and suitable for analysis and recognition [1]. While the majority of data enhancement methods are designed for general scientific use, a few are tailored for industrial object detection and spatial data analysis [2]. Various methods are employed to enhance the performance of image processing applications, aiming to improve the quality of input images. Common issues encountered in medical and spatial images include blurriness, noise, and low contrast [3]. In this paper, we conduct a comparative study of recent image enhancement methods. We analyze qualitative and quantitative outcomes, including color correction, feature enhancement, and noise

reduction, ultimately leading to improved image quality and enhanced accuracy in analysis.

Several common techniques and goals associated with image enhancement include enhancing image contrast, reducing noise, sharpening images, adjusting brightness and gamma, improving color, and modifying histograms. One of the primary objectives of image enhancement is to boost the contrast between various elements within the image. Image enhancement approaches frequently incorporate noise reduction methods, such as filtering, to eliminate undesirable noise. Sharpening images not only enhances their visual appeal but also elevates their quality. Gamma correction is often applied to rectify non-linear intensity relationships within images, making them more visually pleasing and easier to analyze. Histogram equalization redistributes the intensity values in an image to enhance overall contrast. Image enhancement is vital in various fields like medical imaging, satellite image analysis, computer vision, and photography. Its purpose is to render images more informative and suitable for both human perception and machine analysis by emphasizing pertinent features and minimizing undesirable artifacts or noise.

To measure and understand publishing trends within certain domains or bodies of literature, bibliometric analysis seeks to understand these patterns [4]–[8]. This requires quantitatively assessing a variety of literary works, such as books, articles, and other publications. This method, which is widely employed to rate the quality of a course of study, may determine the value and significance of the text's contents. Within a certain academic field, bibliometric research can pinpoint significant publications, authors, organizations, and nations. In these studies, measures like citation counts, h-indices, and journal impact ratings are frequently used. By doing bibliometric analysis or mapping the academic landscape of a subject, one might discover more about the worth and extent of academic contributions and uncover potential areas for future research and collaboration [9]–[14].

The bibliometrix R-package, which is used to do bibliometric analysis, has an online interface called Biblioshiny. The R bibliometrix package contains a number of tools for doing quantitative bibliometric and scientometric research [15]–[17]. By providing a user-friendly, web-based interface to carry out many bibliometric procedures without needing the user to write R code, Biblioshiny streamlines the procedure [18]–[20]. A well-known program for bibliometric analysis and visualization is called VOSviewer [21]–[24]. This application is designed to assist scholars and researchers in visualizing and analyzing the co-authorship networks, bibliographic data, and keyword co-occurrence networks that may be found in academic literature. In-depth publication collections may be explored for patterns and correlations using VOSviewer [25]–[29].

The research objectives of the study are:

- Identify Trends in Image Enhancement Research: Examine the patterns in publications throughout time to see when and if there have been any substantial changes to the techniques or focus of image enhancement research.
- Mapping Research Hotspots: Through clustering and keyword analysis, identify the main study themes and subtopics within image enhancing techniques, indicating regions of intense research effort.
- Evaluating Collaboration Networks: Examine the collaboration networks among researchers, institutions, and countries to identify key players and collaborative trends in the field of image enhancement.
- Geographical and Institutional Analysis: Investigate the geographical distribution of research in image enhancement and identify institutions or countries that are leading in this field.
- Keyword Co-occurrence Analysis: Perform keyword co-occurrence analysis to identify the most common keywords associated with image enhancement, which can provide insights into emerging themes and technologies.
- Recommendations for Future Research: Based on the analysis, provide recommendations for researchers, institutions, and policymakers regarding potential directions for future research and development in image enhancement methods.

2. REVIEW OF LITERATURE

Various fields utilize image enhancement techniques to improve image details for analysis and recognition. In the context of dark underwater areas, conventional image enhancement methods tend to be less effective. In the study by Zhang, D. et. al have proposed an underwater image enhancement approach based on color correction

and multi-scale fusion. This method prevents excessive enhancement while effectively improving exposure in dark regions [30].

In industrial machine vision inspections, a common issue is the lack of sufficient data, and data enhancement can incorporate prior human visual knowledge to enhance model performance. Wan, D., et. al introduce a novel image data enhancement method called Random Interpolation Resize (RIR). They modify the interpolation process in standard resizing, moving from fixed collocation to random selection during preprocessing. This expansion of image data enhances the model's generalization and detection capabilities [2].

One effective approach to image enhancement is to improve the quality of the input image. Medical images often suffer from problems like lack of sharpness, noise, or low contrast. Dinh, P.-H., proposes a new algorithm to enhance the quality of brain Magnetic Resonance Images. Various image enhancement algorithms, including Contrast Limited Adaptive Histogram Equalization (CLAHE), denoising based on Convolutional Neural Networks, and Laplacian edge detection algorithms, are used to enhance input images, resulting in superior model performance compared to recent image enhancement methods [3].

The automatic segmentation of the prostate and prostatic zones in MRI remains a significant research area. The impact of image enhancement on different convolutional neural networks has been largely unexplored. Zaridis, D.I., et. al. proposes a novel image enhancement method, RACLAHE, to enhance the performance of CNN models for segmenting the prostate gland and prostatic zones. This method outperforms four other image enhancement techniques across five CNN models (U-Net, U-Net++, U-Net3+, ResU-net, and USE-NET) [30].

Sekeroglu, B. presents a time-shift image enhancement method to represent constant images in spacetime, derive associated events, and use them to enhance degraded images. This method is evaluated for color correction, detail enhancement, and noise reduction for each dataset. It utilizes the Lorentz factor to represent the movement of objects and can effectively enhance images for various problem domains without causing over- or under-enhancement [31].

Photos taken under nighttime or backlit conditions often suffer from low visibility, noise, and color distortion. To address this, He, X. et. al propose a global-and-local aware network (GLAN). This network incorporates features into the frequency domain and combines global modeling capabilities from transformers with local sensitivity from convolutional neural networks to represent structure and texture [32].

Due to the unpredictable variations in medical images, noise and low contrast problems are common, and physicians require images with good contrast to make accurate diagnoses. Aldoury, R.S., et. al. utilize the generalized k-differential equation based on the k-Caputo fractional differential operator (K-CFDO) to enhance the visual quality and provide a clearly defined problem. This model enhances medical image details, improving the efficiency and accuracy of clinical decision-making [33].

3. MATERIALS AND METHODS

We selected the Scopus database for our research because of its extensive representation of scientific papers across multiple fields. We systematically searched with the term "image enhancement method." This search included all languages and was limited to journal articles and conference proceedings. We gathered essential metadata like titles, authors, affiliations, keywords, abstracts, and references from the Scopus database. We spotted and eliminated duplicate records. Any discrepancies in author names and affiliations were corrected. We collected 1915 articles from 940 unique sources, covering the period from 1979 to 2023. We saved our results in a 'CSV' file and performed a bibliometric analysis using VOSviewer version 1.6.19 and Biblioshiny software. Figure 1 provides a visual representation of our approach, and Table 1 offers detailed insights into the critical components of our study.

Figure 1. The methodology phases

Table 1. Essential aspects of the investigation.

4. RESULTS

4.1. Annual Scientific Production

From Figure 2, as depicted by Biblioshiny, it's evident that the field of image enhancement has seen varying levels of research activity from 1979 to 2023. A marked increase in publications is observed from 2006 to 2022, with 2022 standing out as the year with the most articles, totaling 303. This suggests a heightened interest and significant

advancements in the field during this period. The consistent annual growth rate of 11.2% further underscores the expanding research in image enhancement over the years.

Figure 2. Annual scientific production.

4.2. Subject Area Analysis

Figure 3 presents a pie chart illustrating the distribution of subject areas within the field of image enhancement. The most dominant subject is Computer Science with 1,201 articles, followed by Engineering at 1,046. Physics and Astronomy contributed 475 papers, while Mathematics had 380. Materials Science accounted for 288 articles. Medicine, Earth and Planetary Sciences, Decision Sciences, and Biochemistry, Genetics and Molecular Biology had contributions of 120, 79, 66, and 50 articles respectively. Energy, Chemistry, and Social Sciences had 44, 43, and 34 articles in that order. Other subjects like Chemical Engineering, Environmental Science, Agricultural and Biological Sciences, and Multidisciplinary had contributions ranging from 22 to 27 articles. Neuroscience and Health Professions had 21 and 16 articles respectively. Fewer contributions came from areas like Business, Management and Accounting (13), Arts and Humanities (6), and Economics, Econometrics and Finance (4). The least represented subjects, with contributions ranging from 1 to 4 articles, include Psychology, Veterinary, Dentistry, Immunology and Microbiology, and Pharmacology, Toxicology and Pharmaceutics.

Figure 3. Documents by subject area

4.3. Most Significant Authors

A collective contribution from 3874 authors was made in the realm of image enhancement study. The volume of their publications serves as a testament to their prominence in the field. Wang Y emerged as the preeminent author, having penned 50 papers, closely followed by Wang X with 48. Wang H also made a notable contribution with 46 papers. Table 2 offers a snapshot of the publication counts of these top authors. Their profound expertise and extensive knowledge have cemented their positions as pivotal experts in the field, thereby magnifying their impact.

Table 2. The top authors

4.4. Most relevant sources and affiliations

In our comprehensive study, we meticulously examined a total of 940 journal references, from which we gathered an impressive 1915 papers. Our analysis revealed the top 10 journals that have published the most research articles explicitly focusing on image enhancement methods. Figure 4 visually showcases these leading journals. Topping the list is "Proceedings of Spie - The International Society for Optical Engineering" with 118 articles. This is followed by "Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)" with 40 articles, "IEEE Access" with 35, and "Multimedia Tools and Applications" with 26. Other notable mentions include "Proceedings - International Conference on Image Processing, ICIP" with 25 articles, "IET Image Processing" with 24, "Lecture Notes in Electrical Engineering" with 23, "Journal of Physics: Conference Series" with 19, "ACM International Conference Proceeding Series" with 18, and "Communications in Computer and Information Science" with 14 articles.

Figure 4. The ten leading sources based on the number of publications

Figure 5 provides an overview of the leading institutions in the realm of image enhancement methods. Topping the list is Dalian Maritime University with a significant 118 mentions. Following closely are Tianjin University with 70 mentions, Huazhong University of Science and Technology with 48, and Sichuan University with 47. Zhejiang University has been mentioned 44 times, while Nanjing University of Posts and Telecommunications and Nanjing University of Science and Technology have 43 and 41 mentions respectively. Jilin University has 40 mentions, Guilin University of Electronic Technology has 38, and rounding off the list is Nanjing University of Aeronautics and Astronautics with 36 mentions. These institutions stand out as the frontrunners in advancing image enhancement techniques.

Figure 5. Most significant affiliations based on the number of publications

4.5. Three Field Plot of keyword, author and source

The "Three Field Plot" in Biblioshiny is a visualization tool that allows users to see the

relationship between keywords, authors, and sources in a bibliometric dataset. By displaying these three fields simultaneously, users can gain insights into the distribution and co-occurrence of keywords across different authors and sources. The keyword (on the left) field displays the keywords extracted from the dataset. It helps users identify the main topics or themes present in the dataset. By looking at the keywords, users can quickly understand the primary focus of the research articles or publications. Author (centrally) field shows the authors of the research articles or publications. By placing the authors centrally, users can see which authors are associated with which keywords and sources. This can help identify leading researchers in specific areas or topics. Source (on the right) field displays the sources (e.g., journals, conferences, etc.) where the research articles or publications are published. By examining the sources, users can identify the leading journals or conferences in a particular research area.

Figure 6 displays a schematic illustrating the links between keywords (to the left), authors (centered), and journals (to the right) within the realm of image enhancement. A study of the predominant keywords, researchers, and journals highlighted terms such as "image enhancement," "underwater image enhancement," “color correction,” “deep learning,” “low-light image enhancement,” and "contrast enhancement." Prominent authors like Zhang Y, Wang Y, Wang H, Zhang W, and others frequently used these phrases in their research, which was often published in journals like Proceedings of SPIE – The International Society for Optical Engineering and IEEE Access. The Three Field Plot is especially useful for bibliometric analysis, where researchers aim to understand the landscape of a particular research domain. By visualizing the relationships between keywords, authors, and sources, users can identify trends, gaps, and potential areas for further research.

Figure 6. Three Field Plot in Biblioshiny displays the keyword on the left, the author centrally, and the source on the right.

4.6. Trend Topics

The study investigated prevailing themes by scrutinizing keywords selected by authors from the supplied data, adhering to specific criteria: the exploration covered 2010 to 2023, keywords had to be mentioned at least five times, three keywords were chosen for each year, and a word label size of five was employed. Generally, the keywords authors choose reflect the core theme of their work, providing a glimpse into the principal subjects in the field. This scrutiny underscores the dominant themes in the literature concerning image enhancement methods over the years. Figure 7 graphically depicts the organization of these keywords, accentuating yearly dialogues on various aspects of image enhancement methods among scholars. For example, "unsupervised learning" led the topic in 2023 with 12 references, "underwater image enhancement" was paramount in 2022 with 93 references, and "image fusion" was cited 38 times in 2021.

Figure 7. Trend topics identified using Biblioshiny from 2010 to 2023

4.7. Tree Map

Figure 8 displays the tree map, created with Biblioshiny, illustrating author keywords. A tree map in the context of bibliometric analysis is a visualization tool that provides a hierarchical view of data. In the case of author keywords in Biblioshiny, a tree map would visually represent the distribution and frequency of keywords used by different authors in their publications. The entire tree map represents all the keywords in the dataset. The size of each section (or "leaf") of the tree map corresponds to the frequency of a particular keyword. Within the tree map, keywords might be grouped by themes or topics. For instance, in Figure 9, keywords associated with "image enhancement" are clustered together, tallying a frequency of 682. This is succeeded by “underwater image enhancement,” which appears 93 times. Different colors can represent different authors or the frequency of keywords. For example, more frequently used keywords might be represented in a darker shade than less frequent ones. By examining a tree map, users can quickly identify the most frequently used keywords, understand the major themes or topics in a dataset, and see which authors contribute to which research areas.

Figure 8. Tree Map

4.8. Country Co-Authorship Analysis

Country co-authorship analysis is a bibliometric method used to study the collaboration between researchers from different countries. By analyzing

co-authorship patterns, one can gain insights into the international collaboration dynamics in a particular research field or domain. This type of analysis can provide valuable information about the global research landscape, the flow of knowledge across borders, and the strength of research ties between nations. Figure 9 illustrates the intricate web of international collaborations through nodes and connections. The magnitude of each node indicates a country's prominence, while the connections denote cross-border institutional collaborations. The closeness and thickness of these connections emphasize the robustness of these partnerships. Different colors on the map depict various research domains. China leads in publication numbers with 1133, succeeded by the United States at 138 and India at 136. In terms of citations, China is prominent with 8727, followed by the United States with 2780 and Taiwan with 1481, showcasing their significant influence in the field. Moreover, China, the United States, and the United Kingdom are predominant in overall connection strength, highlighting their central positions in this international co-authorship matrix.

Figure 9. The network visualization of country co-authorship analysis

4.9. Co-occurrence of Keywords

The VOSviewer tool was utilized to depict clusters of commonly used keywords related to image enhancement techniques. From a total of 10862 keywords, 928 were chosen for examination, given they occurred a minimum of 5 times. Figure 10 showcases the results. Analyzing keyword co-occurrence can provide insights into the relationships between different research topics and help identify emerging trends or interdisciplinary areas of study. Co-occurrence can be visualized using network diagrams where nodes represent keywords and edges (or links) represent the co-occurrence frequency. The thickness or color of the edges can indicate the strength of the co-occurrence. The examination identified eight unique clusters, each containing a different count of keywords. Significantly, "image enhancement" stood out, being mentioned 1648 times, succeeded by "color" with 253 mentions and "image processing" cited 220 times.

Figure 10. The network visualization of keyword co-occurrence

5. DISCUSSION

The meticulous bibliometric analysis, grounded in a robust methodology and utilizing the comprehensive Scopus database, has unfolded a rich tapestry of research in the realm of image enhancement methods spanning over four decades (1979-2023). With a substantial corpus of 1915 articles derived from 940 unique sources, the study not only underscores the sustained and escalating academic interest in this field but also provides a panoramic view of its evolution and current state. The utilization of advanced bibliometric tools, namely VOSviewer and Biblioshiny software, has enabled a nuanced exploration of the data, revealing patterns, networks, and trends that are pivotal for scholars and practitioners alike. This study, therefore, not only serves as a mirror reflecting the historical and contemporary landscape of image enhancement research but also acts as a beacon, guiding future endeavors in this ever-evolving domain.

The study underscores the dynamic evolution of research in the field of image enhancement from 1979 to 2023. The period from 2006 to 2022, in particular, marks a pivotal era of intensified research activity, culminating in 2022 with a record number of 303 articles. This surge in publications not only signifies a burgeoning interest among researchers but also points to notable advancements and innovations in image enhancement techniques during this timeframe. The sustained annual growth rate of 11.2% further attests to the field's progressive trajectory, emphasizing its relevance and significance in the broader scientific community.

The study unveils a compelling narrative about the distribution of research across various subject areas within the field of image enhancement. Predominantly anchored in Computer Science, with a substantial 1,201 articles, and closely followed by Engineering at 1,046, the research landscape evidently leans heavily towards technical and computational domains. This underscores the pivotal role that algorithmic and computational methodologies play in advancing image enhancement techniques. The noteworthy contributions from Physics and Astronomy (475 articles) and Mathematics (380 articles) highlight the interdisciplinary nature of image enhancement, demonstrating its applicability and significance in various scientific explorations and theoretical developments. Meanwhile, the participation from Materials Science and Medicine, with 288 and 120 articles respectively, underscores the practical and

impactful applications of image enhancement in diverse fields, from improving material characterization to enhancing medical diagnostics. Interestingly, the analysis also reveals a modest but crucial contribution from areas like Earth and Planetary Sciences, Decision Sciences, and Biochemistry, Genetics and Molecular Biology, indicating the expansion of image enhancement methods into specialized and emerging research arenas. The minimal representation from subjects like Psychology, Veterinary, and Economics, Econometrics and Finance, with contributions ranging from 1 to 4 articles, suggests potential untapped opportunities for applying image enhancement techniques in these domains.

In light of these findings, it is imperative to acknowledge the expansive and multifaceted nature of image enhancement research, which permeates through various scientific disciplines, each harnessing its capabilities to refine and augment visual data. The future of image enhancement research beckons a more integrated approach, potentially fostering collaborations across diverse disciplines, to explore innovative applications and address unique challenges pertinent to each field. This could pave the way for novel methodologies that amalgamate domain-specific expertise with advanced image enhancement techniques, propelling the field towards new horizons of scientific and practical breakthroughs.

The bibliometric analysis reveals a robust and vibrant research environment within the realm of image enhancement, substantiated by a collective contribution from 3,874 authors. The voluminous publications not only underscore the significance of the field but also spotlight the authors who have notably shaped its trajectory. Wang Y, Wang X, and Wang H have emerged as pivotal figures, contributing 50, 48, and 46 papers respectively, thereby establishing themselves as preeminent experts in the domain. Their prolific output, not only underscores their individual expertise but also reflects their substantial impact on the evolution and development of image enhancement methodologies. The collective endeavors of all the authors have undeniably enriched the field, providing a foundation upon which future research can build. Moving forward, the insights and methodologies proposed by these leading authors will likely continue to influence and inspire subsequent research endeavors, steering the direction of future innovations and applications in image enhancement.

Our exhaustive bibliometric analysis, encompassing 1915 papers from 940 journal references, has provided a clear insight into the leading journals in the realm of image enhancement methods. The "Proceedings of Spie - The International Society for Optical Engineering" stands out as the foremost journal in this domain, contributing 118 articles. It is evident that "Lecture Notes in Computer Science," "IEEE Access," and "Multimedia Tools and Applications" are also pivotal contributors, with significant numbers of articles. The diversity of journals, ranging from conference proceedings to specialized image processing journals, underscores the widespread interest and multidisciplinary nature of image enhancement research. As the field continues to grow, these journals will likely remain central hubs for disseminating cutting-edge research on image enhancement methods.

The study elucidates a compelling narrative of institutional leadership and contribution in the sphere of image enhancement methods. Dalian Maritime University emerges as a pivotal player, boasting a noteworthy 118 mentions, thereby underscoring its influential role and substantial impact in steering the research trajectory in this domain. The future of image enhancement research, seems promising and is likely to witness further breakthroughs, potentially through collaborative endeavors and knowledge sharing among the leading institutions. This robust foundation paves the way for exploring novel methodologies and enhancing the applicability and efficacy of image enhancement methods across diverse fields and applications.

A meticulous examination of the keywords such as "image enhancement," "underwater image enhancement," “color correction,” “deep learning,” “low-light image enhancement,” and "contrast enhancement" has not only underscored the pivotal research themes but also spotlighted the prevailing trends and challenges within the image enhancement research. The central positioning of authors, including notable contributors like Zhang Y, Wang Y, Wang H, and Zhang W, has facilitated an understanding of the researchers who are at the forefront, steering the direction of the discourse in this domain. Furthermore, identifying the key publication sources, particularly the Proceedings of SPIE – The International Society for Optical Engineering and IEEE Access, has provided insights into the platforms that are recognized as authoritative in disseminating impactful research in this field.

The synthesis of these three pivotal elements through the Three Field Plot has not only mapped the current research landscape but also highlighted

potential avenues and gaps that warrant further exploration. By discerning the interplay between the thematic keywords, authors, and sources, researchers, practitioners, and policymakers are better positioned to navigate, contribute to, and shape the future trajectory of image enhancement research. This analysis, therefore, not only serves as a reflective lens on the existing body of work but also as a compass, guiding subsequent research endeavors towards areas that may yield substantial advancements in the field of image enhancement.

The bibliometric analysis of keywords from 2010 to 2023 offers a revealing insight into the evolving landscape of image enhancement methods. By setting stringent criteria for keyword selection, the study ensures that only the most significant and recurrent themes are highlighted. The choice of keywords by authors serves as a mirror to the central concerns and innovations in the field. Notably, the prominence of "unsupervised learning" in 2023, the surge in interest for "underwater image enhancement" in 2022, and the attention to "image fusion" in 2021 exemplify the diverse and progressive directions the field is taking. These findings underscore the importance of staying abreast with the latest trends and adapting to the ever-evolving challenges and opportunities in image enhancement research.

The bibliometric analysis, as visualized through the tree map, underscores the pivotal themes and keywords prevalent in the realm of image enhancement research. The hierarchical and clustered representation of author keywords not only delineates the frequency of keyword usage but also provides a structured view of the thematic concentrations within the dataset. The predominant focus on "image enhancement," evidenced by its substantial frequency of 682, signifies its central role and the extensive research efforts dedicated to this domain. Moreover, the notable mention of “underwater image enhancement” with a frequency of 93, highlights a specialized sub-domain that has garnered attention, potentially due to the unique challenges and applications associated with underwater imaging. The visualization tool, in this context, not only encapsulates the current research landscape but also acts as a guide, pointing towards potential future directions in image enhancement research. It is imperative that future research endeavors consider these prevalent themes while also exploring underrepresented areas to foster a holistic advancement in the field. Furthermore, the collaborative exploration of authors into various thematic areas, as indicated by the tree map, suggests a future research trajectory that is likely to be interdisciplinary and multifaceted, intertwining various aspects of image enhancement to cater to the diverse and evolving application scenarios.

The bibliometric exploration, particularly through the lens of country co-authorship analysis, has unveiled pivotal insights into the global dynamics and collaborative networks in the research field under study. The intricate web of international collaborations, not only underscores the collective pursuit of knowledge across borders but also highlights the pivotal role of certain nations in steering the research direction and collaborations in this domain. China has emerged as a colossal entity in this research landscape, leading not only in the volume of publications but also in the influence gauged through citations, with 1133 publications and 8727 citations respectively. The United States and India also mark their substantial presence, albeit with a stark contrast in publication numbers when juxtaposed with China. The citation count further accentuates the substantial impact and recognition of the research emanating from these nations, with the United States and Taiwan following China in citation prominence. Moreover, the robustness of international partnerships, particularly involving China, the United States, and the United Kingdom, signifies a potent research nexus, potentially acting as a catalyst in propelling advancements and disseminating knowledge in the field.

The meticulous exploration of keywords in the realm of image enhancement techniques, facilitated by the VOSviewer tool, has unveiled pivotal insights into the prevailing and emergent trends within the research community. The prominence of "image enhancement," which was cited a staggering 1,648 times, underscores its pivotal role and persistent relevance in the field. Followed by keywords like "color" and "image processing," it is evident that the research landscape is not only vast but also intricately interwoven with various sub-domains and related fields. The identification of eight distinct clusters further delineates the multifaceted nature of image enhancement research, hinting at the potential for specialized studies and advancements within each cluster. The co-occurrence network diagrams have not only mapped the interrelationships among diverse research topics but also spotlighted potential avenues for interdisciplinary research and innovation. Moving forward, the research community might leverage these insights to steer their investigations towards unexplored intersections and synergies within image enhancement and related domains, thereby contributing to the holistic evolution of the field.

This comprehensive bibliometric analysis distinctly justifies the significant contribution of Information Technology (IT) in the realm of image enhancement. Through the meticulous examination of a vast corpus of literature, the results underscore how IT has been instrumental in evolving image enhancement methods over the decades. Advanced IT methodologies, particularly in computational techniques and algorithmic developments, have been the cornerstone of significant improvements in image processing. This study's findings demonstrate that IT has not only driven the field's technical advancements but also catalyzed interdisciplinary integration, paving the way for innovative applications across various domains. The new knowledge created, is the clear delineation of the evolution, current trends, and potential future trajectories of IT-driven image enhancement methods. These insights are critical for guiding future research, encouraging an integrated approach that combines IT expertise with domain-specific needs, thereby driving the field of image enhancement towards new horizons of innovation and practical application.

6. LIMITATIONS

This research relies on the Scopus database, and as a result, it might not include important studies from other sources, which could introduce a selection bias. By concentrating only on journal articles and conference papers, we might have overlooked useful information found in other types of documents like books, theses, or technical reports.

7. CONCLUSION

The comprehensive bibliometric analysis undertaken in this study offers an in-depth overview of the research trajectory in image enhancement over the past decades. This investigation highlights a notable uptick in publications, signifying escalating interest and the increasing significance of this field. This analysis meticulously identifies key contributors – authors, institutions, and countries – that have been instrumental in advancing image enhancement techniques. Furthermore, through the analysis of prevalent keywords, we have pinpointed trending topics and central areas of research, reflecting the evolving nature of image enhancement methodologies. The findings reveal a marked evolution in image enhancement methods, with newer approaches emerging to overcome the limitations of traditional techniques. As the technological landscape continues to evolve rapidly, we anticipate that image enhancement will experience further innovative breakthroughs, meeting the diverse demands of applications ranging from medical imaging to satellite imagery. The future of this field, as suggested by this analysis, is likely to be shaped by collaborative efforts, interdisciplinary research, and the integration of cutting-edge technologies like artificial intelligence and machine learning.

In line with the research objectives, this study not only traces the historical and present-day trends in image enhancement research but also sheds light on key thematic areas and technological transitions. The comprehensive approach, encompassing the identification of research trends to the dissection of collaborative networks, offers a multifaceted view of the field. Notably, this research underscores the pivotal role of interdisciplinary collaboration and the integration of advanced computational methods, especially from Information Technology, in driving the evolution of image enhancement. This study, therefore, not only deepens the understanding of the field's progression but also sets a platform for future research directions, advocating for innovative and collaborative exploration across various scientific and technological spectrums. The insights derived from this analysis serve as a strategic guide, pointing researchers and practitioners toward promising avenues for continued advancement and exploration in the realm of image enhancement methods.

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Table 1. Essential aspects of the investigation.

Description	**Results**
Search Query	(TITLE-ABS-KEY("Image enhancement Method") AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp")))
Main Information about Data	
Timespan	1979:2023
Sources (Journals, Books, etc)	940
Documents	1915
Annual Growth Rate %	11.2
Document Average Age	6.37
Average citations per doc	9.514
References	40359
Document Contents	
Keywords Plus (ID)	8854
Author's Keywords (DE)	3882
Authors	
Authors	3874
Authors of single-authored docs	77
Authors Collaboration	
Single-authored docs	84
Co-Authors per Doc	3.77
International co-authorships %	10.29
Document Types	
Article	1053
conference paper	862

Table 2. The top authors

Authors	**Articles**
Wang Y	50
Wang X	48
Wang H	46
Li Y	43
Zhang Y	43
Zhang W	34
Liu X	33
Liu J	32

Yang J	32
Li J	31
Zhang J	31
Liu H	29
Li L	28
Wang Z	28
Zhang X	28

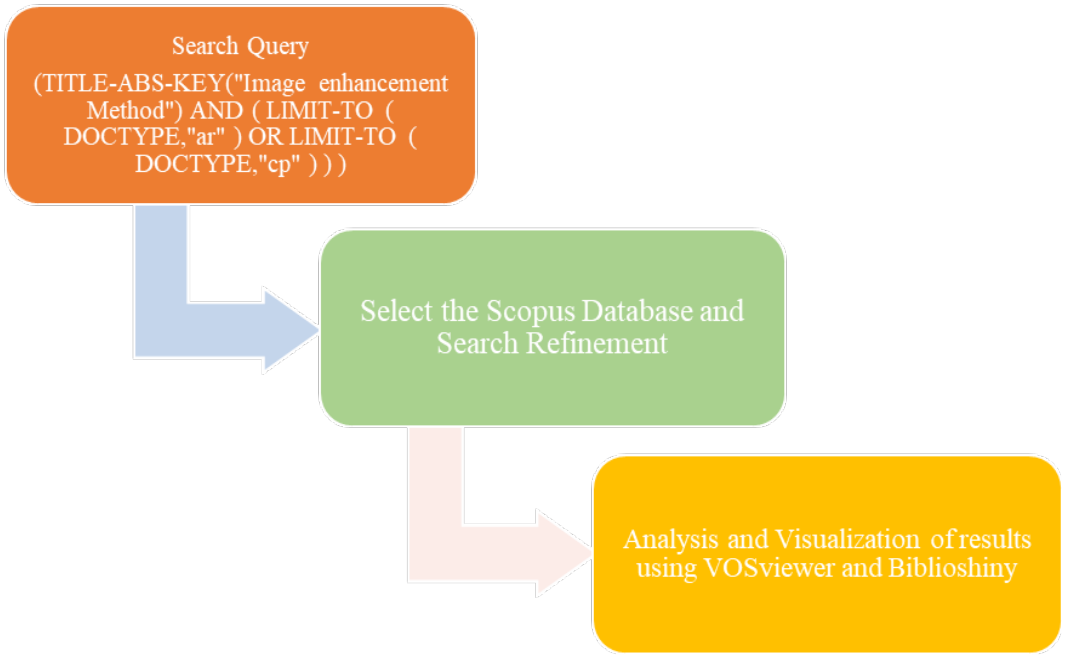

Figure 1. The methodology phases

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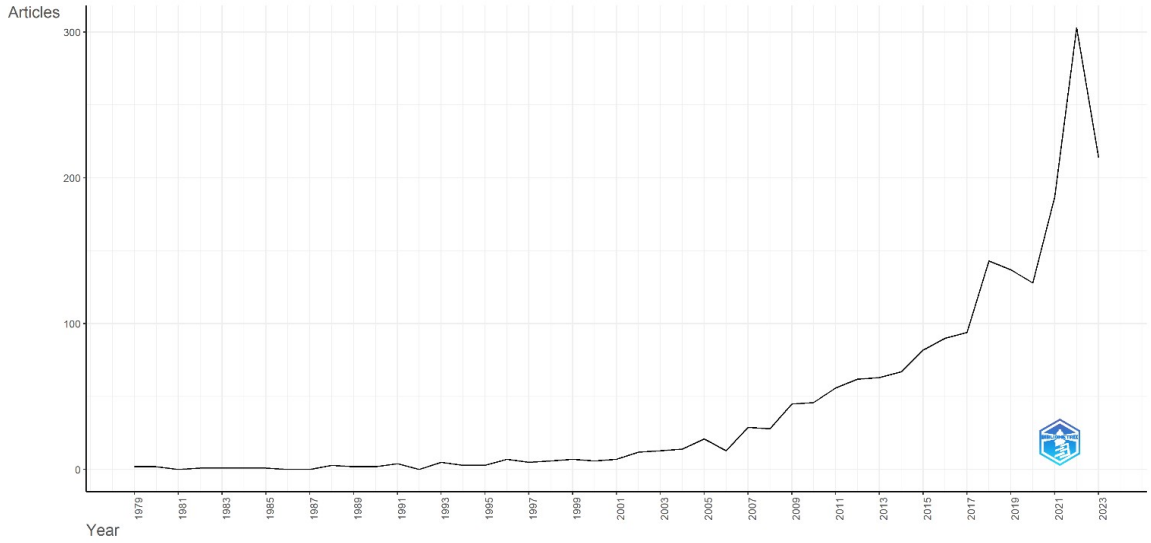

Figure 2. Annual scientific production.

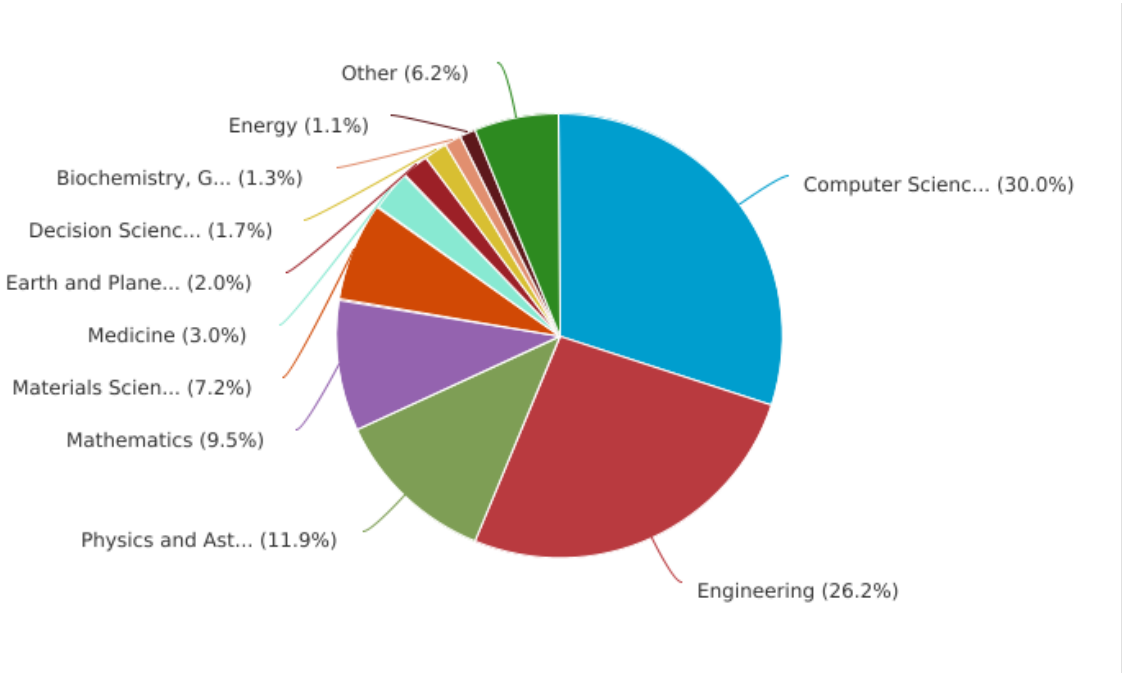

Figure 3. Documents by subject area

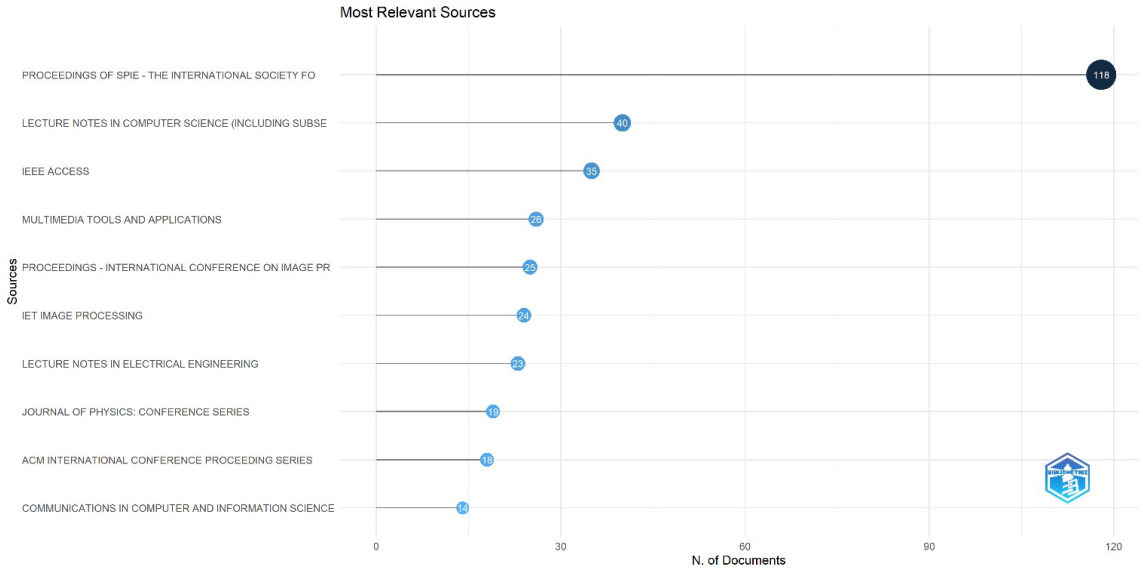

Figure 4. The ten leading sources based on the number of publications

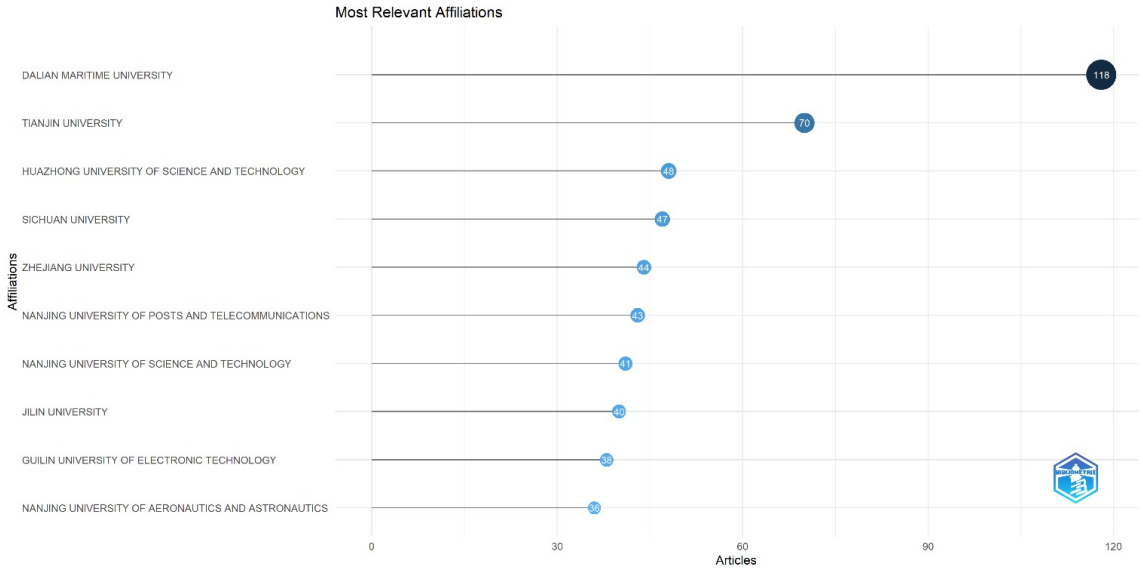

Figure 5. Most significant affiliations based on the number of publications

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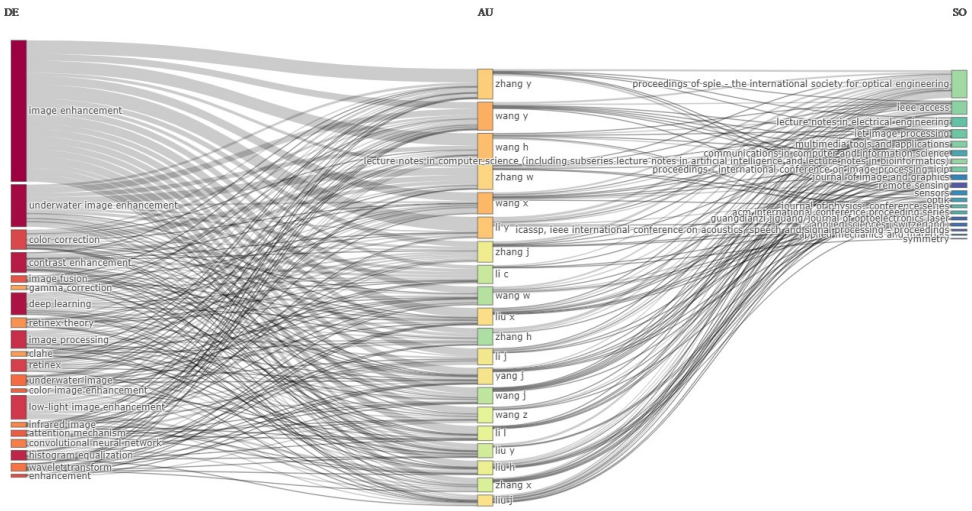

Figure 6. Three Field Plot in Biblioshiny displays the keyword on the left, the author centrally, and the source on the right.

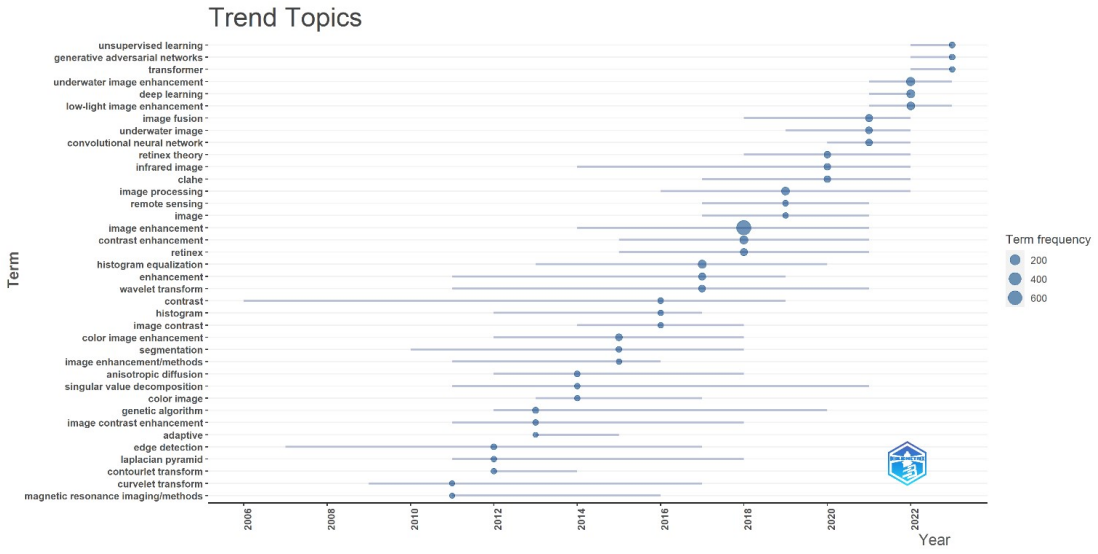

Figure 7. Trend topics identified using Biblioshiny from 2010 to 2023

Figure 8. Tree Map

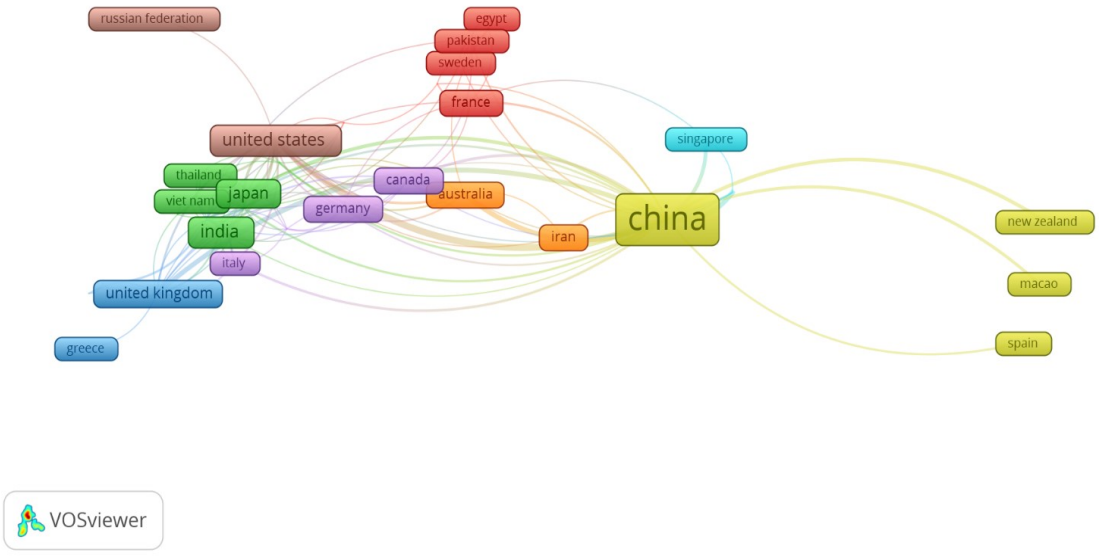

Figure 9. The network visualization of country co-authorship analysis

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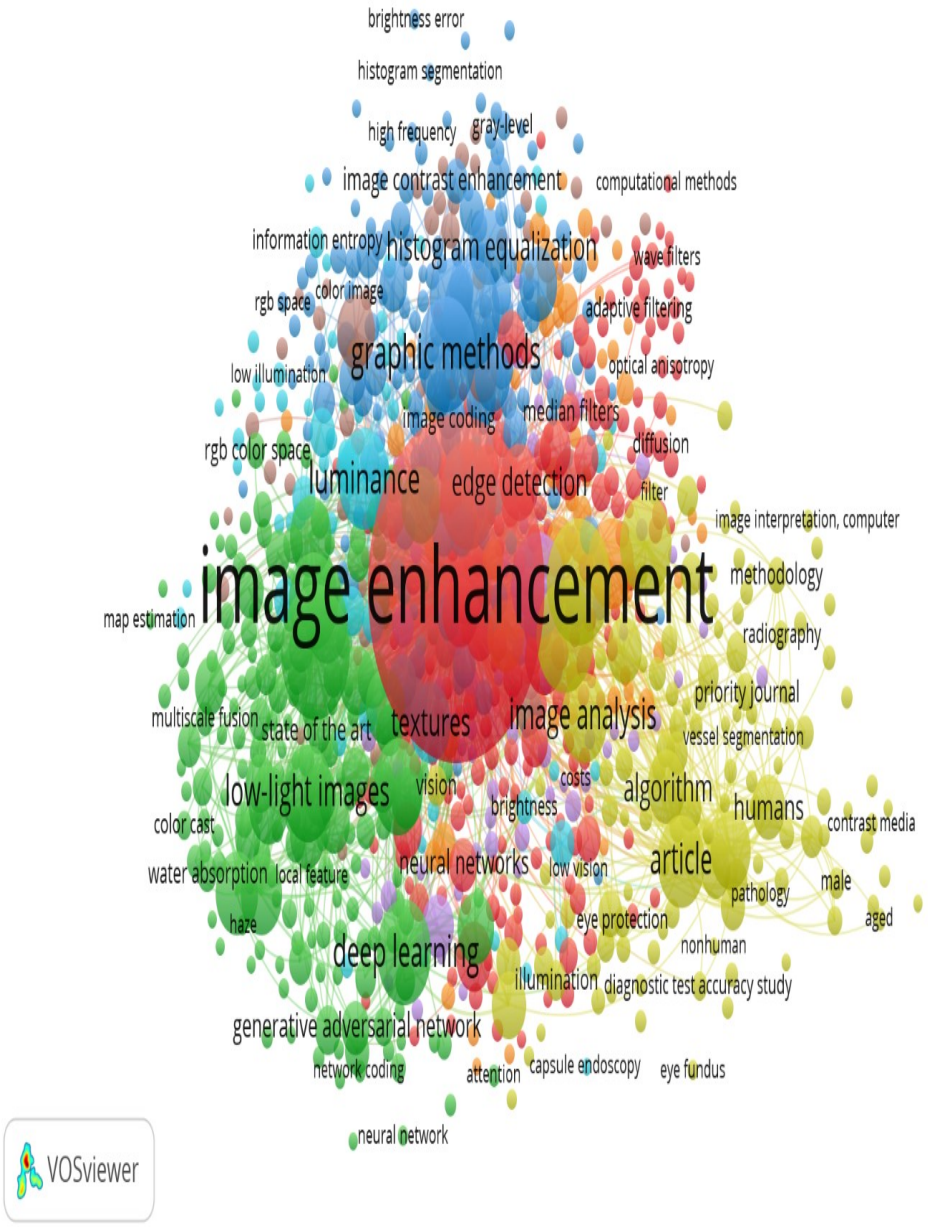

Figure 10. The network visualization of keyword co-occurrence