Bibliometric Analysis of Scientific Production of Intelligent Video Surveillance

Review Paper

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Abstract *– This article offers a bibliometric analysis of academic research in intelligent video surveillance, evaluating its evolution between 2000 and 2024. 1,343 documents were collected from the Scopus database and the PRISMA methodology was applied to organize the search and selection of relevant publications. The findings show a notable increase in the number of studies, reaching its highest point in 2022, driven by advances in artificial intelligence, the Internet of Things (IoT) and deep learning. China leads scientific production in this field, followed by India and the United States. Main research areas include real-time surveillance using deep learning methods, sequential and transfer learning techniques, as well as the use of advanced YOLO, Faster-RCNN and RFCN algorithms in controlled environments; however, detecting unusual behavior is a latent challenge.*

Keywords*:* *video, iot, cybersecurity, surveillance, behavioral detection*

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1. INTRODUCTION

Smart video surveillance has emerged as a key tool in the protection and monitoring of public spaces, not only because of its ability to prevent crime, but also because of its suitability to process large volumes of information in real time. These technologies provide proactive detection of suspicious or dangerous behavior, facilitating quick and effective responses from authorities. A central aspect of intelligent video surveillance is its integration with deep learning algorithms and cloud-based systems or fog computing, which allow real-time image processing without overloading traditional cloud infrastructures [1]. This capability significantly improves safety, as intelligent systems can identify objects or people in potentially dangerous situations, improving incident response capability [2]. In addition, the use of artificial intelligence in these systems not only optimizes the efficiency of surveillance, but also presents the possibility of respecting privacy through algorithms designed to anonymize individuals in situations where no immediate risks are detected. However, it is crucial to take into account the public perception regarding privacy and the associated risks, as studies have shown that a considerable percentage of the population perceives these systems as invasive, which can affect their acceptance in society [2].

Smart video surveillance is an advanced system leveraging artificial intelligence technologies, such as deep learning, to enhance event detection and enable real-time decision-making. By integrating sensors and cameras with Internet of Things (IoT) networks, these systems can automatically identify suspicious behavior or anomalies within a given environment. This approach is crucial for improving security in urban areas, enabling authorities to respond swiftly to potential threats [1]. In addition, implementing fog computing in these systems reduces latency and improves data processing efficiency, which is essential for real-time surveillance applications [3].

A key aspect of smart video surveillance is its capacity for continuous learning and improvement. Machine learning algorithms in these systems can be regularly trained on new data, enhancing their accuracy in detecting incidents, even in complex scenarios or environments with multiple elements. These capabilities not only make it possible to identify objects or people, but also to predict unusual behaviors before they become a serious problem [2]. In addition, advanced algorithms based on the behavior of tuna swarms, combined with deep learning techniques, have proven effective in identifying violent acts in real-time within surveillance platforms [4].

In addition to security aspects, smart surveillance systems must face ethical challenges, especially in terms of respect for privacy and the management of personal data. Public acceptance of these systems depends to a large extent on how the balance between security and the protection of individual privacy is managed. Concerns about possible misuse of the collected data are common, forcing developers to incorporate various actions that ensure the processing of data that is actually necessary for security purposes (Golda et al., 2022). For this, it is essential to establish a legal framework that clearly regulates the collection, processing, and protection of personal information [5].

Smart video surveillance has been implemented internationally in various contexts to improve public safety and optimize the response to critical situations. An example of its application is the use of surveillance systems based on fog computing in Saudi Arabia, where an intelligent monitoring system has been deployed for the recognition of suspicious actions in real time. This system uses distributed cameras and advanced image processors to detect potential threats and generate alerts to the competent authorities, thus achieving a faster and more effective response [1]. Another significant example is in Germany, where public perceptions of smart video surveillance systems in public spaces were assessed. These systems have been used to detect risks in mass events, such as concerts or protests, where automated monitoring makes it possible to identify dangerous behaviors and prevent safety incidents before they occur [2]. These cases reflect how smart video surveillance has been adapted to local needs, improving both public safety and social acceptance in different countries.

This analysis of publications indexed in databases such as Scopus aims to identify the primary algorithms based on deep neural networks that enable the development of real-time intelligent video surveillance systems, particularly for object detection and tracking. Additionally, it seeks to evaluate the impact and evolution of research in the field of Intelligent Video Surveillance.

2. METHOD

2.1. SEARCH STRATEGY

This study follows a bibliometric methodology, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach. The data was obtained from the Scopus database on September 3, 2024, using the search terms: TITLE ("Video surveillance" AND "Smart"). Scopus was selected as the primary database for this study due to its extensive coverage of scientific publications in various disciplines, as well as its ability to provide comprehensive and consistent metadata. Instead, Web of Science was discarded, despite its wide access to high-quality academic research, as most of the journals it indexes (approximately 99%) are already included in Scopus, which would lead to redundant data collection without adding additional value to bibliometric analysis [6]. Google Scholar was also excluded due to its limited ability to provide the specific information needed for bibliometric analysis. Although Google Scholar is a useful tool for general literature searches, it lacks advanced features such as citation display and precise categorization by document type and relevance, making it inappropriate for studies that require a more rigorous and systematic bibliometric approach [7].

The flowchart (Fig. 1) shows the process of selecting the documents. The document selection process began with the identification of 1,406 records extracted from the Scopus database, based on specific search terms. Various exclusion criteria were then applied to purify the initial sample.

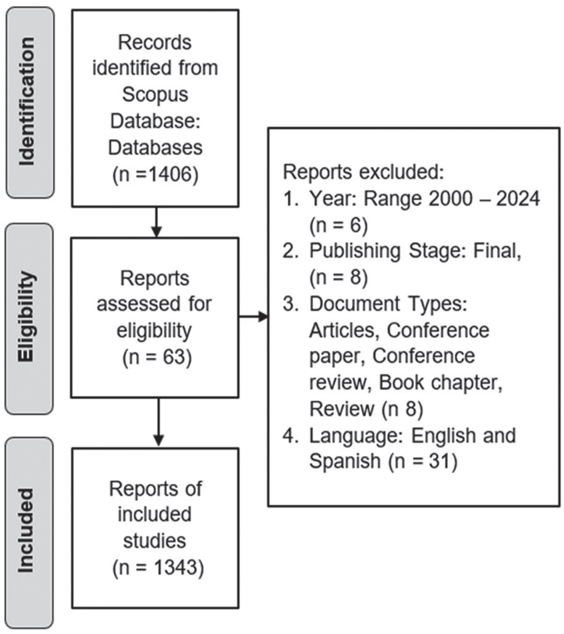

Fig. 1. Graphical representation of the record filtering process based on the PRISMA approach

First, six documents that did not correspond to the time range defined for the study, which spanned from the year 2000 to September 3, 2024, were discarded.

Eight studies that were not at a final publication stage, i.e. those that were under review or had not yet been fully published, were also removed.

Then, a more detailed selection was made according to the type of document, prioritizing scientific articles, conference proceedings, reviews and book chapters, while other non-relevant formats were excluded. Finally, in the selection by language, 31 publications written in languages other than Spanish or English were eliminated, since only these two languages were considered suitable for the present analysis. After this rigorous selection process, a total of 1,343 documents were retained for bibliometric analysis, complying with the previously established inclusion criteria.

2.2. DATA ANALYSIS

The collected data was organized and analyzed using the open-source software "bibliometrix R-package", widely recognized for its ability to process and visualize bibliometric data efficiently. This tool allowed an exhaustive analysis of scientific production in intelligent video surveillance, identifying the main research trends and mapping collaboration networks between authors, institutions and countries. Through the Biblioshiny graphical interface, time evolution graphs were generated that evidenced the significant growth of publications from 2017 onwards, driven by advances in artificial intelligence and the Internet of Things (IoT). Additionally, co-citation analysis and keyword co-occurrence techniques were used to identify the relationships between the most prolific researchers and emerging topics in this field. The results were presented in tables and figures, providing an overview of the current state of research, the predominant areas and the most relevant international collaborations, making it easier to identify development patterns and possible areas of future study.

3. RESULTS AND DISCUSSION

3.1. EVOLUTION OF SCIENTIFIC PRODUCTION

In Fig. 2, the production of 1,343 scientific articles generated during a period of 25 years (2000 to September 3, 2024) is shown.

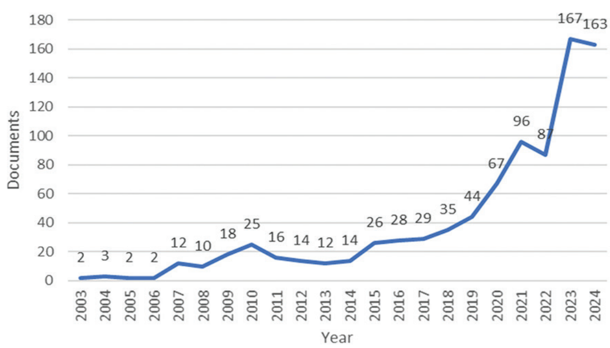

Fig. 2. Growth in the number of annual publications

The graph shows that between 2000 and 2016, scientific production in intelligent video surveillance remained moderate and stable, with slight fluctuations that did not exceed 52 annual publications. This suggests that, during this period, the technology was still in an emerging phase, facing technological limitations and lack of infrastructure for its mass implementation. As of 2017, there has been an exponential growth in the number of publications, reaching a peak in 2022 with 148 documents, reflecting the growing interest driven by advances in artificial intelligence and big data, which have been fundamental for the development of intelligent surveillance systems. However, in 2024 there is a significant decrease in the number of publications, with only 79 documents to date, which could be related to the saturation of the topic or the shift towards new technological areas such as differential privacy [8].

3.2. MORE PRODUCTIVE JOURNALS

Fig. 3 shows that 25.24% of the total publications were issued by the top 20 journals, which shows an uneven distribution.

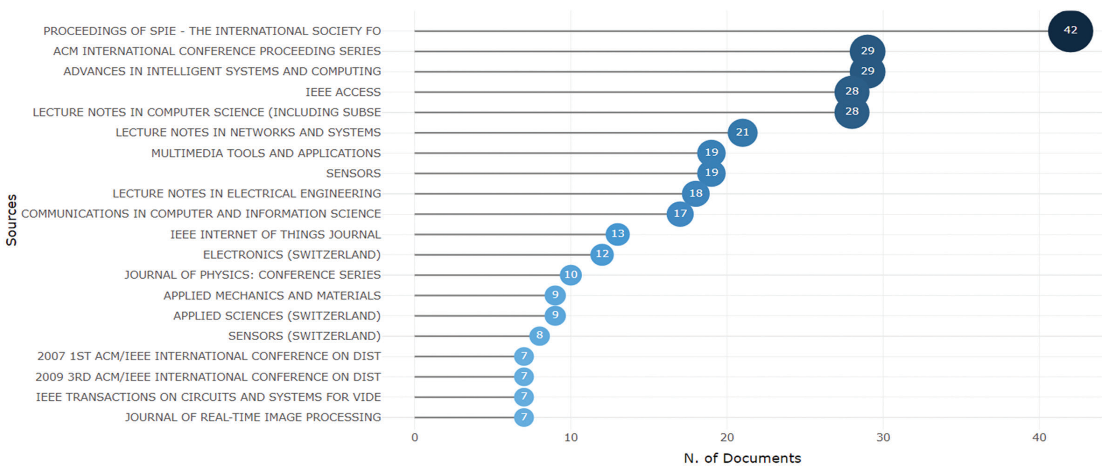

Fig. 3. Most relevant sources on smart video surveillance

Taking into account PROCEEDINGS OF SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING (42) the source with the most documents available, followed by ACM INTERNATIONAL CONFERENCE PROCEEDING SERIES (29), ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING (29), IEEE ACCESS (28), LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS) (28), LECTURE NOTES IN NETWORKS AND SYSTEMS (21), MULTIMEDIA TOOLS AND APPLICATIONS (19), SENSORS (19), LECTURE NOTES IN ELECTRICAL ENGINEERING (18), COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE (17), IEEE INTERNET OF THINGS JOURNAL (4), IEEE INTERNET OF THINGS JOURNAL (13), ELECTRONICS (SWITZERLAND) (12), JOURNAL OF PHYSICS: CONFERENCE SERIES (10), APPLIED MECHANICS AND MATERIALS (9), APPLIED SCIENCES (SWITZERLAND) (9), SENSORS (SWITZERLAND) (8), 2007 1ST ACM/IEEE INTERNATIONAL CONFERENCE ON DISTRIBUTED SMART CAMERAS, ICDSC (7), 2009 3RD ACM/IEEE INTERNATIONAL CONFERENCE ON DISTRIBUTED SMART CAMERAS, ICDSC 2009 (7), IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY (7) y JOURNAL OF REAL-TIME IMAGE PROCESSING (7). In general terms, the set of sources indicates that research in this field is highly favored by the integration of various disciplines, such as electrical engineering, computing, artificial intelligence and optics. International congresses and conferences, especially those organized by SPIE and ACM, are essential for the dissemination and exchange of knowledge, which justifies their relevance in the graphic. This underlines the key role played by these specialized forums in driving the progress and dissemination of technologies linked to Smart Video Surveillance.

3.3. MORE PRODUCTIVE JOURNALS

Fig. 4 shows the 20 most influential authors based on the number of articles in Scopus. The leading in the number of publications are NA NA, Wang Y, Chen Y, Zhang Y, Rinner B, Wang S, Xu Z, Zhang X, Ahamed I, Giorgi R, Li H, Li J, Li Y, Liu Y, Tian Y, Zhang J, Hampapur A, Singh S, Wang L, Wang X. The analysis of the writings of these renowned authors provides researchers with a comprehensive view that facilitates a deeper understanding of the field of study, as well as a critical reflection on the methodologies employed in their own research.

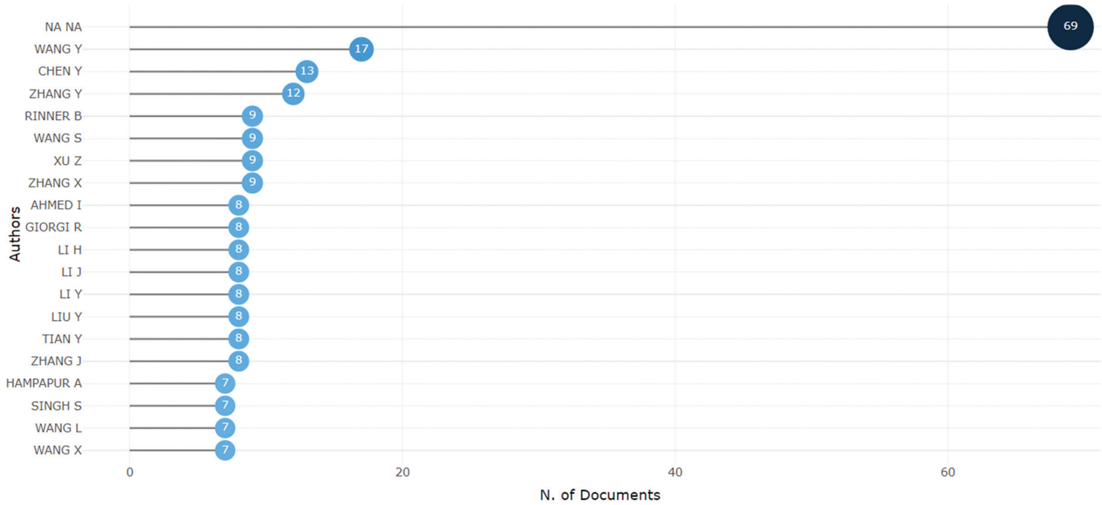

Fig. 4. Authors with the greatest influence according to the number of publications in Scopus

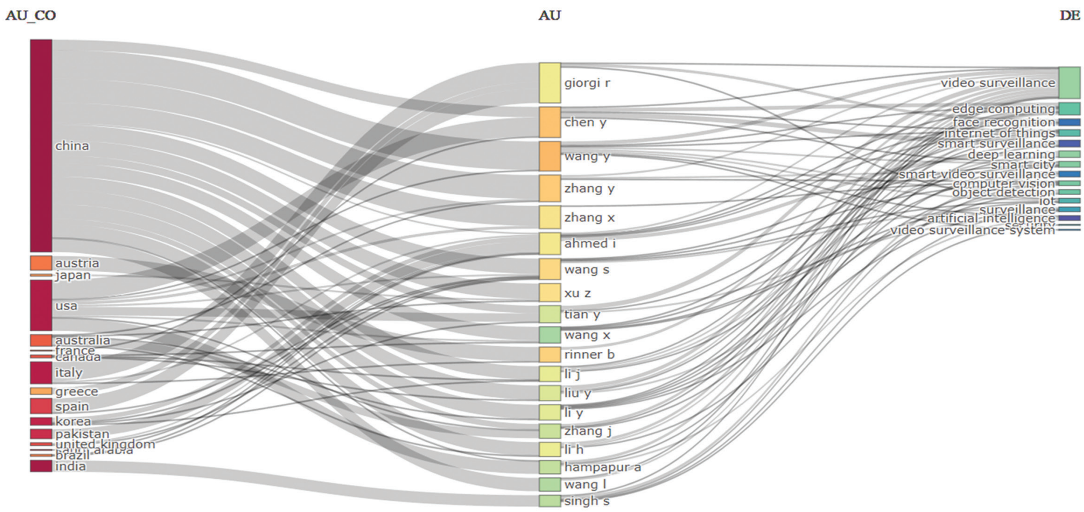

Fig. 5. Three-field chart (countries, authors, and keywords)

In Figure 5, the three-field graph, based on Sankey's diagrams [9], exposes the most influential authors and countries according to the most relevant keywords in the research.

It is noted that China is the country with the most publications, and the topic of "intelligent video surveillance" is widely discussed, especially among academics in the United States, Italy and Spain.

3.4. SCIENTIFIC CONTRIBUTION BY COUNTRY

In the research on "smart video surveillance", China is positioned as the main contributor with 535 publications. India follows with 402, and the United States has 199.

Italy, South Korea, Pakistan, Saudi Arabia, Spain, Germany and the United Kingdom complete the group of the 10 most active countries in this field, with 142, 104, 73, 63, 60, 59 and 57 publications, respectively (See Fig. 6).

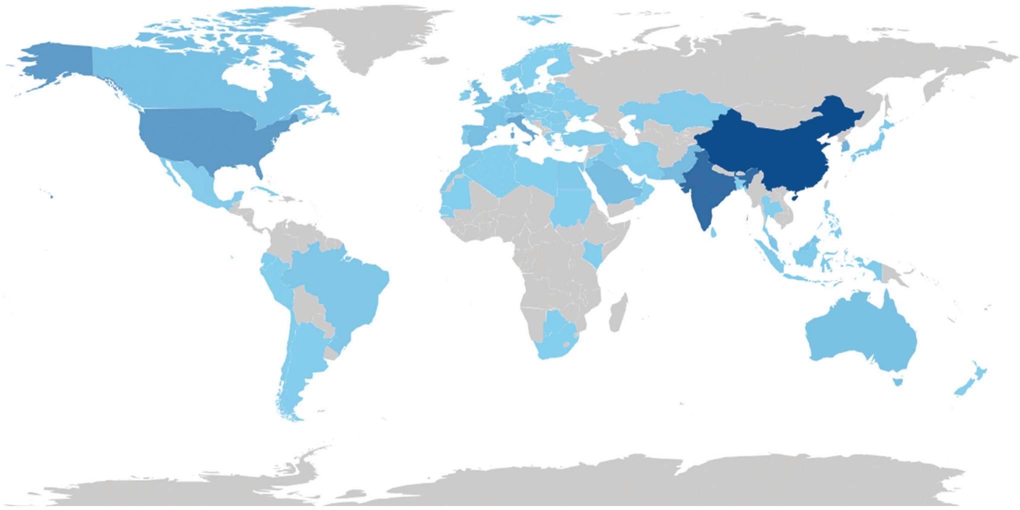

Fig. 6. Number of Articles by Country (blue shade: country or region with posts, grey shade: country or region with no posts, blue intensity: most posts)

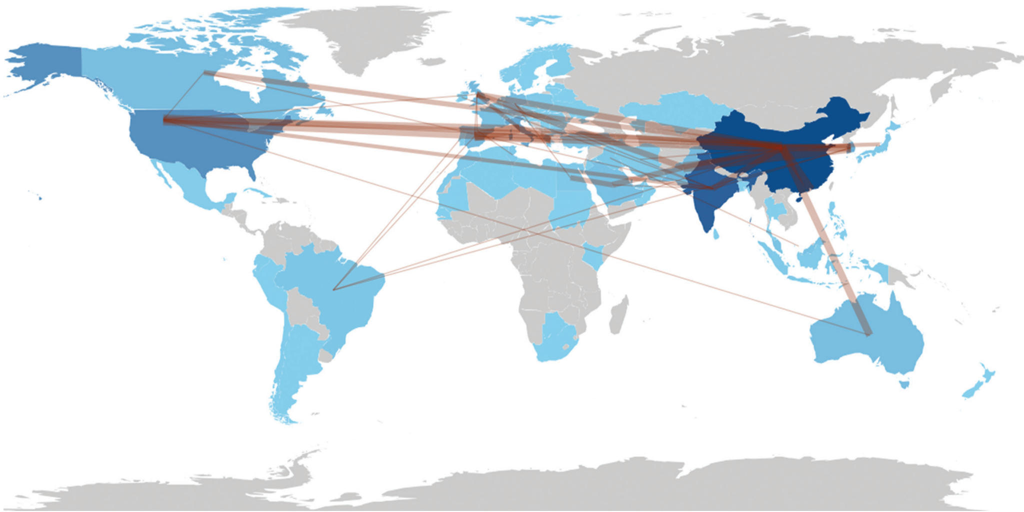

Fig. 7. Country collaboration map

3.5. MOST INTERNATIONALLY REFERENCED PUBLICATIONS

Table 1 shows the findings of the 20 most cited articles globally on Intelligent Video Surveillance [10-29], including CHAABOUNI N, 2019, IEEE COMMUN SURV TUTOR leads with 635 citations in total (105.83 per year), HAMPAPUR A, 2005, IEEE SIGNAL PROCESS MAG with 268 citations in total (13.40 per year); MEMOS VA, 2018, FUTURE GENER COMPUT SYST with 266 citations in total (38 per year); MINOLI D, 2018, INTERNET THING with 254 citations in total (36.29 per year); BAI Y, 2018, IEEE TRANS MULTIMEDIA with 234 citations in total (33.43 per year); ZHOU X, 2021, IEEE INTERNET THINGS J with 230 citations in total (57.50 per year); ZHANG T, 2015, PROC ANNU INT CONF MOBILE COMPUT NETWORKING with 227 citations in total (22.70 per year); The table includes articles published in a variety of relevant journals and conferences, not only in surveillance and security, but also in related fields such as communication networks, artificial intelligence, and mobile computing (e.g., Hampapur et al., 2005 in IEEE Signal Processing

Magazine and Minoli, 2018 in Internet of Things). This diversity shows that research on intelligent video surveillance is not limited to a single domain, but spans several disciplines, reinforcing its multidisciplinarity and applicability in different technological fields.

Table 1. Ranking of the 20 most referenced scientific articles worldwide

Paper	DOI	Total Citations
CHAABOUNI N, 2019, IEEE COMMUN SURV TUTOR	10.1109/ COMST.2019.2896380	635
HAMPAPUR A, 2005, IEEE SIGNAL PROCESS MAG	10.1109/ MSP.2005.1406476	268
MEMOS VA, 2018, FUTURE GENER COMPUT SYST	10.1016/ j.future.2017.04.039	266
MINOLI D, 2018, INTERNET THING	10.1016/ j.iot.2018.05.002	254
BAI Y, 2018, IEEE TRANS MULTIMEDIA	10.1109/ TMM.2018.2796240	234
ZHOU X, 2021, IEEE INTERNET THINGS J	10.1109/ JIOT.2021.3077449	230
ZHANG T, 2015, PROC ANNU INT CONF MOBILE COMPUT NETWORKING	10.1145/ 2789168.2790123	227
MEHTA P, 2020, COMPUT COMMUN	10.1016/j. comcom.2020.01.023	205
FRAGA-LAMAS P, 2017, SENSORS	10.3390/ s17061457	175
LINGXIAO H, 2019, PROC IEEE INT CONF COMPUT VISION	10.1109/ ICCV.2019.00854	165
YADAV SK, 2021, KNOWL BASED SYST	10.1016/ j.knosys.2021.106970	158
NAYAK R, 2021, IMAGE VISION COMPUT	10.1016/ j.imavis.2020.104078	158
TIAN Y, 2011, IEEE TRANS SYST MAN CYBERN PT C APPL REV	10.1109/ TSMCC.2010.2065803	158
FLECK S, 2008, PROC IEEE	10.1109/ JPROC.2008.928765	141
SHORFUZZAMAN M, 2021, SUSTAINABLE CITIES SOC	10.1016/ j.scs.2020.102582	135
SAPONARA S, 2021, J REAL-TIME IMAGE PROCESS	10.1007/ s11554-020-01044-0	130
WANG F, 2020, IEEE ACCESS	10.1109/ ACCESS.2020.2982411	130
HOLTE MB, 2012, IEEE J SEL TOP SIGN PROCES	10.1109/ JSTSP.2012.2196975	123
PAISITKRIANGKRAI S, 2008, IEEE TRANS CIRCUITS SYST VIDEO TECHNOL	10.1109/ TCSVT.2008.928213	119
KE R, 2021, IEEE TRANS INTELL TRANSP SYST	10.1109/ TITS.2020.2984197	113

3.6. KEYWORD ANALYSIS

Analyzing keywords is essential, as it allows us to identify the most relevant topics within the field of research [3]. Figure 8 reveals that "security systems" and "video surveillance" are the terms that predominate, evidencing that the central focus of research on intelligent video surveillance is on security and monitoring. This fact highlights the growing importance of surveillance systems in the protection of critical infrastructures, the prevention of crime and the reinforcement of both public and private security, which suggests a constant advance in the development and application of these technologies in different sectors.

Fig. 8. Word Cloud

Fig. 9 reflects the growth of the most significant keywords over the years. The top ten keywords comprise SECURITY SYSTEMS, VIDEO SURVEILLANCE, MONITORING, CAMERAS, DEEP LEARNING, VIDEO SURVEILLANCE SYSTEMS, NETWORK SECURITY, INTERNET OF THINGS, SMART CITY, and OBJECT DETECTION. Video surveillance analytics has advanced significantly with the use of deep learning and anomaly detection, which has allowed for more efficient identification of suspicious patterns in real-time. According to [30], these methods reduce the amount of data to be analyzed by focusing on critical patterns, alleviating the human workload. This advance explains the exponential growth of investigations into security and video surveillance systems observed in the graph since 2015.

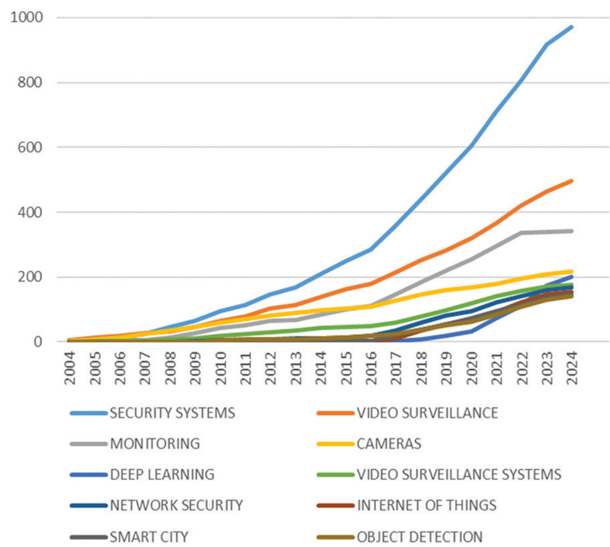

Fig. 9. Most Developed Words

3.7. MORE PRODUCTIVE JOURNALS

The thematic map provides a detailed interpretation of the patterns and trends of the topics of study, including information on seasonality and outliers. These maps divide the topics into four quadrants, using centrality on the X-axis and density on the Y-axis as classification criteria. Centrality indicates the connectivity and relevance of a topic in the general scope, while density reflects the degree of cohesion and development within the cluster [31]. As can be seen in Figure 10, the topics are classified into four categories: motors, the most connected and developed; basic topics, which although well connected, still have room to develop; niche topics, highly cohesive but less globally connected; and emerging issues, which are still nascent but with a potential significant future impact.

Motor themes. This quadrant includes the topics with the highest centrality and density, which means that they are well-developed topics with great impact within the field of intelligent video surveillance. Examples of these topics include "security," "real-time surveillance," and "object detection," which are critical in smart video surveillance applications. A clear example of a driving theme is CrowdSurge's article: A Crowd Density Monitoring Solution Using Smart Video Surveillance with Security Vulnerability Assessment. This article proposes a crowd density monitoring solution that uses intelligent video surveillance to manage public safety. This issue is critical in mass events or demonstrations, where security depends largely on the ability to monitor the density of people in real time, something that is also key in emergency management. This type of technology is developed in environments where safety is a priority concern [32]

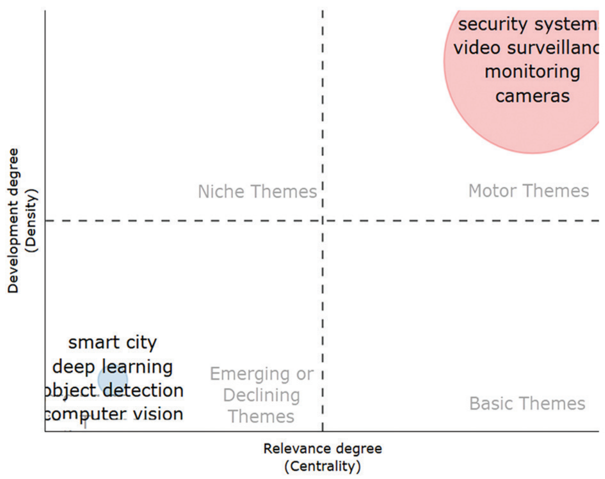

Fig. 10. Theme map

The basic themes. This quadrant includes topics that, although highly relevant, have not yet reached a high degree of development. These are central areas for the field that need more attention and research. A clear example of a basic topic in this quadrant is the article Abnormal human behavior detection in videos: A review. The detection of abnormal behaviors in surveillance systems is of great relevance, especially in public safety and crime prevention. However, despite their relevance, the development of practical solutions remains limited, with challenges in accuracy and real-time contextual recognition [5].

The Niche Themes: This quadrant is empty, indicating the absence of topics that are highly developed yet hold low central relevance to global research on intelligent video surveillance. In other words, there are no specialized areas within the field that are highly advanced but lack significant impact or importance in the broader context of the discipline.

Emerging or Declining Themes: This quadrant highlights various methods, techniques, and algorithms leveraging both online and offline deep learning. Identification algorithms, such as YOLO, are particularly effective in surveillance systems deployed in controlled environments like hallways, rooms, warehouses, banks, and parking lots. Additionally, highly accurate and efficient algorithms such as Faster-RCNN and RFCN are notable for detecting potential threats in images, such as identifying dangerous objects like weapons during baggage scans at airports. Offline algorithms are best suited for preprocessing tasks, such as analyzing an individual's behavior in previously recorded video sequences [26, 27]. Meanwhile, Sort and Deep Sort algorithms stand out as the most efficient for object tracking, balancing accuracy and speed, for example tracking pedestrians and vehicles.

4. CURRENT CHALLENGES AND FUTURE STUDIES

Intelligent Video Surveillance faces several key challenges related to the integration of emerging technologies such as IoT and artificial intelligence, which are still in the early stages of adoption and present interoperability problems between hybrid systems [10, 11]. In addition, cybersecurity and data privacy are critical concerns, due to the vulnerabilities of cloud-connected systems and the large amount of sensitive information that is collected [10, 12]. There are also challenges in real-time image processing and accurate object detection in dynamic environments, such as vehicular traffic, which requires high accuracy and speed [11, 14]. Latency and efficiency in managing large volumes of data in the cloud remain major issues, especially in connected cities, where the integration of multiple data sources is complex [12, 13]. Finally, energy consumption in devices with artificial intelligence is a key challenge to ensure continuous and efficient surveillance [14]. In summary, the main challenges encompass security, privacy, interoperability, and efficiency in the processing and energy consumption of these systems.

Smart Video Surveillance faces a number of key challenges that span several technological aspects. One of them is the synchronization between sensor networks and real-time processing algorithms, which requires advances in 5G [15], along with the heterogeneity of connected devices, which generates problems of standardization and compatibility of hardware and software. Compressing video to reduce bandwidth without affecting quality remains a challenge, especially in mobile applications, where resources are limited [16]. Quality of service (QoS) in video surveillance networks is another challenge, especially in areas with poor network infrastructure, which affects real-time transmission [17]. It is also necessary to improve the computational efficiency of machine learning models to handle large volumes of data and improve the accuracy in the detection of events and objects [33, 34]. In addition, latency in data transmission and scalability issues of IoT-based systems complicate real-time monitoring [18]. Finally, adverse lighting and weather conditions, as well as efficiency in training deep learning models with large datasets, represent significant computational challenges [19].

One of the great challenges of Intelligent Video Surveillance is the protection of privacy, as the vast amount of personal data handled raises ongoing concerns [20]. Detecting and tracking objects in dense urban environments, with multiple people and moving vehicles, remains challenging, especially in conditions of variable lighting and visual interference [35, 36]. In addition, the integration of fixed and mobile surveillance cameras poses data processing and compatibility issues, while synchronization between multiple cameras distributed in a system remains a considerable challenge [22, 23]. In addition, in sustainable cities, the high energy consumption of cameras and sensors poses challenges in terms of efficient energy use, while integration with smart urban technologies, such as transport networks and waste management, requires advances in interoperability and technological standards [24].

Future studies on smart video surveillance focus on incorporating new technologies, such as deep learning and IoT, to improve object segmentation and detection in dynamic and complex urban environments [21]. A key area of research is the refinement of multi-target tracking algorithms in distributed systems, along with the reduction of energy consumption for implementation in smart cities [37-39]. In addition, progress is needed in the synchronization and transmission of data between networked cameras, improving the efficiency of storage and processing in systems with limited infrastructures [40, 41]. Since smart cities require sustainability, it is crucial to develop energy-efficient technologies that do not compromise the performance of video surveillance systems [24]. Finally, improving real-time processing algorithms to handle large volumes of data without losing accuracy or speed is a major challenge in future research [25].

The future of intelligent video surveillance should focus on improving cybersecurity, developing more robust network architectures to protect data against cyberattacks [42, 43]. Another crucial aspect is the advance in the recognition of human actions through computer vision algorithms, which make it possible to distinguish between suspicious and routine behaviors in crowded environments such as airports and stations [44, 45]. In addition, research is needed to improve the compression and efficient transmission of high-resolution video, ensuring the quality of images in real time without consuming too much bandwidth, especially in areas with limited infrastructure [28, 29]. In the field of transport, studies should advance in the integration of video surveillance with road infrastructures to analyse the behaviour of drivers and pedestrians, improving road safety [46-48]. Finally, emerging technologies such as artificial intelligence and blockchain are essential to ensure data security and integrity, facilitating more reliable monitoring in complex scenarios such as smart cities [49-51].

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