

Bibliometric Analysis of Research Articles on Embedded Internet of Health Things (IoHT) Fall Detection in the Elderly Published from 2006 to 2025

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Background: Falls are a major cause of injury and death among the elderly, highlighting the need for effective and real-time detection systems. Embedded Internet of Health Things (IoHT) technologies integrating sensors, microcontrollers, and communication modules offer continuous monitoring and rapid response. However, the research landscape remains fragmented, and no comprehensive bibliometric review has been conducted.

Methods: This study presents a bibliometric analysis of articles on embedded IoHT-based fall detection for the elderly, indexed in Scopus from 2006 to April 2025. Keywords related to embedded systems, IoHT, fall detection, and elderly care were used. Data extracted included publication year, type, country, institution, author, citations, and methodology. Analysis included performance metrics, science mapping, and visualization using VOSviewer.

Results: A total of 79 publications were found, mostly conference papers (55.7%) and journal articles (39.2%). Research activity increased notably after 2018, peaking in 2024. India, China, and the United States led in volume, while Spain and Ecuador produced highly cited works, especially on wearable and IoT-based solutions. Thematic analysis revealed four clusters: ambient intelligence, inertial sensors, demographic personalization, and networked wearables linked to telemedicine. Methodologies evolved from threshold-based to advanced AI, including machine learning, deep learning, and edge/cloud integration. Key gaps remain in standard datasets, privacy, and equitable demographic representation.

Conclusion: Embedded IoHT fall detection research has grown rapidly, shifting toward AI-driven, clinically integrated, and user-centered systems. Future efforts should focus on standardization, privacy frameworks, and inclusive design to ensure broader real-world application in elderly care.

Keywords: fall detection, elderly, embedded systems, Internet of Health Things, IoHT, bibliometric analysis, wearable sensors, machine learning, smart homes, healthcare technology, sensor fusion

Introduction

Falls represent one of the most significant health risks for the elderly population worldwide, often resulting in severe injuries, hospitalization, and even fatalities.¹ According to global health statistics, approximately 30% of people aged 65 and older experience at least one fall annually, with this percentage increasing to 50% for those over 80 years of age.² The consequences of falls extend beyond physical injuries to include psychological impacts such as fear of falling, reduced mobility, social isolation, and diminished quality of life.¹ With the global aging population projected to reach 2.1 billion by 2050, addressing fall-related health challenges has become an urgent public health priority requiring innovative technological interventions.^{2,3}

The emergence of the Internet of Health Things (IoHT) has created unprecedented opportunities for real-time monitoring and early intervention in elderly healthcare.⁴ While the Internet of Things (IoT) broadly encompasses

interconnected devices across various domains, IoHT represents a specialized branch focused specifically on healthcare applications, encompassing medical sensors, wearable devices, and systems that collect, analyze, and transmit health data.⁵ Within this domain, embedded systems—which integrate computing capabilities within physical devices using microcontrollers, sensors, and actuators—have shown remarkable potential for developing effective fall detection solutions. These embedded IoHT systems enable continuous monitoring without human intervention, allowing for immediate alert generation when falls are detected.³

Fall detection research using embedded IoHT has evolved substantially over the past decade, progressing from simple threshold-based approaches to sophisticated machine learning and deep learning methodologies.¹ Early systems primarily relied on wearable accelerometers with predefined threshold values to identify falls but suffered from high false alarm rates and limited sensitivity.² Contemporary research increasingly leverages the fusion of multiple sensor types (motion, physiological, and environmental) with advanced algorithms to achieve more accurate detection while addressing challenges related to privacy, power consumption, and user acceptance.^{3,4,6}

Despite the growing body of literature in this field, there has been no comprehensive bibliometric analysis examining the research landscape of embedded IoHT fall detection systems for elderly care. Bibliometric analysis represents a systematic and quantitative method for exploring large volumes of scientific data, offering insights into research trends, influential works, collaboration networks, and emerging topics.⁷ Such analysis is invaluable for researchers seeking to understand the intellectual structure and evolution of this interdisciplinary field that spans healthcare, computer science, engineering, and gerontology.

The purpose of this study is to conduct a thorough bibliometric analysis of research articles focusing on embedded IoHT fall detection systems for the elderly. By examining publication patterns, citation structures, author collaborations, and thematic developments, we aim to map the intellectual landscape of this field, identify research hotspots, and highlight emerging trends.⁷ This study employs established bibliometric techniques including performance analysis and science mapping using specialized tools such as VOSviewer.

Our analysis specifically addresses four key research questions:¹ How has research output in embedded IoHT fall detection evolved over time in terms of volume and impact?² Which countries, institutions, and authors have been most productive and influential in this field?³ What are the dominant research themes and how have they shifted over time?⁴ What methodological approaches are most prevalent and how are they evolving?

Methods

Data Source and Search Strategy

We conducted a comprehensive literature search using the Scopus database (Elsevier). The Scopus database was selected for this study due to its comprehensive coverage of peer-reviewed scientific literature across multiple disciplines and its compatibility with bibliometric analysis tools such as VOSviewer. The analysis covers the period from January 1, 2006, to April 24, 2025; therefore, publication data for the year 2025 should be considered provisional, as it reflects only partial-year results and may not represent the full research output for that year. The search strategy with keyword (“embedded” OR “integrated” OR “inbuilt”) AND (“internet” OR “web” OR “network”) AND (“health” OR “wellness” OR “medical”) AND (“things” OR “devices” OR “objects”) AND (“fall” OR “collapse” OR “trip”) AND (“detection” OR “monitoring” OR “identification”) AND (“elderly” OR “aged” OR “senior” OR “geriatric”). These keywords were applied to titles, abstracts, and author keywords using Boolean operators. No language restrictions were initially applied.

Data Extraction and Coding

Bibliographic data were extracted for each eligible publication, including title, authors, year of publication, journal, and the first author’s country of affiliation. In addition, bibliometric indicators such as citation counts and author keywords were recorded. Data extraction was performed independently by two reviewers using a piloted extraction sheet to ensure accuracy and consistency. Any discrepancies were resolved through discussion.

Bibliometric and Network Analysis

Bibliometric analyses were conducted to examine annual publication trends, including the number of articles published per year and the overall growth trajectory. We identified the most productive authors, institutions, countries, and journals, evaluating both publication volume and citation impact. Collaboration patterns, including co-authorship and international collaborations, were analyzed through network maps generated using VOSviewer (version 1.6.18). Keyword co-occurrence analysis was also performed to detect thematic clusters and emerging areas of research interest.

Statistical Analysis

Descriptive statistics, including frequencies, percentages, means, and standard deviations (SD), were calculated using Microsoft Excel 2021. These metrics were used to quantitatively summarize publication characteristics and bibliometric indicators.

Visualization

Visual representations of the findings were generated to facilitate interpretation. Co-authorship networks and keyword co-occurrence maps were created with VOSviewer, using a minimum threshold of five occurrences per term. Temporal trends and geographic distributions were visualized through trend charts and heatmaps produced using Microsoft Excel 2021.

Results

A total of 79 documents were identified. Conference papers represented the majority of records ($n = 44$; 55.7%), followed by journal articles ($n = 31$; 39.2%), book chapters ($n = 2$; 2.5%), and review papers ($n = 2$; 2.5%). Nearly all publications were in English ($n = 78$; 98.7%), with one document in Chinese ($n = 1$; 1.3%). By source type, 36 documents (45.6%)

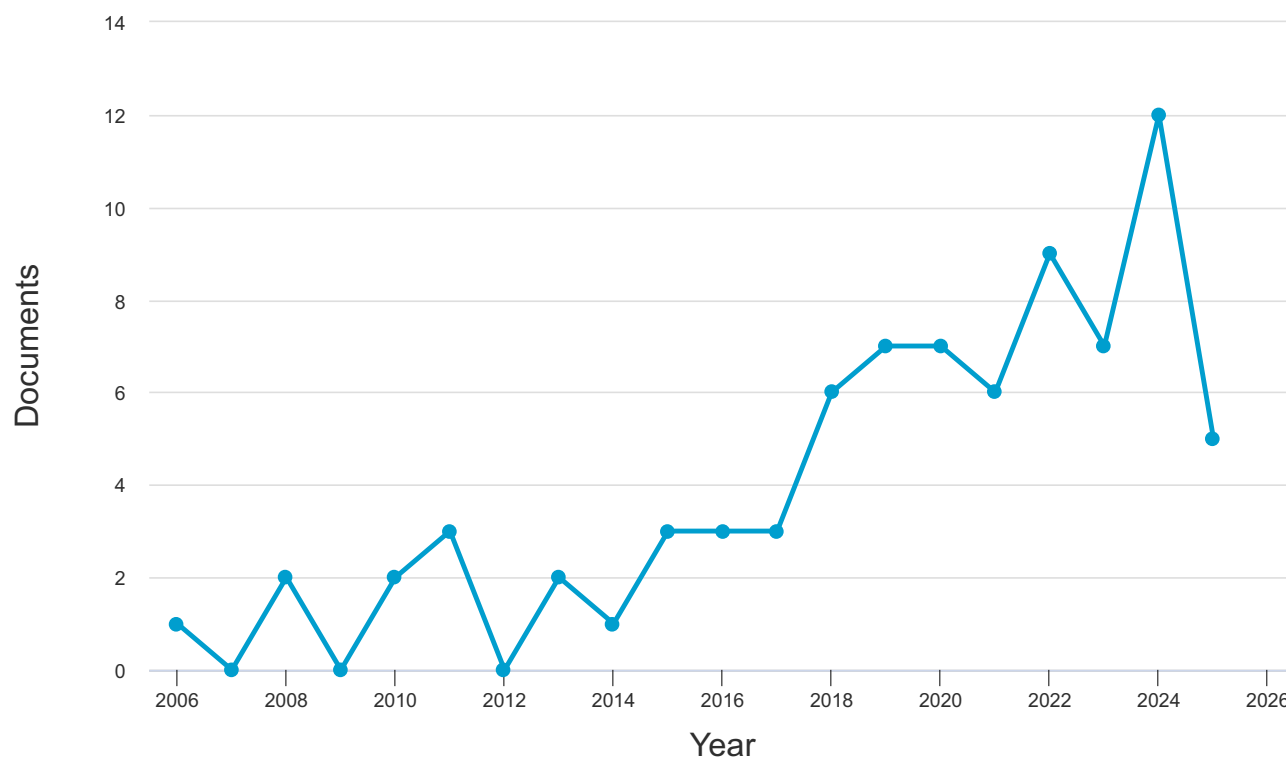


Figure 1 Documents by year from 2006 to 2025.

Notes: Figure 1 Documents by year from 2006 to 2025 shows the annual output of Scopus-indexed publications on embedded systems, the Internet of Health Things, and fall detection in older adults. Between 2006 and 2012, output remained low and variable, peaking at three documents in 2011 before dropping to zero in 2012. From 2013 to 2017, publication counts rose gradually, stabilizing at 1–3 papers per year. A marked acceleration began in 2018, when six documents were published—rising to seven in both 2019 and 2020, dipping slightly to six in 2021, then climbing to nine in 2022. Although the count fell back to seven in 2023, it surged to a record twelve papers in 2024. As of April 24, 2025, five documents had been recorded (data for 2025 remain provisional). Overall, the trend underscores a rapid increase in research interest in IoHT and fall-detection technologies for the elderly over the past five years.

appeared in conference proceedings, 32 (40.5%) in peer-reviewed journals, 9 (11.4%) within book series, and 2 (2.5%) as standalone books.

The annual trend of publications on embedded IoHT-based fall detection shows a rapid increase after 2018, peaking in 2024 (Figure 1).

Analysis of the Table 1 top 20 most-cited articles in embedded Internet of Healthcare Things (IoHT) fall detection reveals that, between 2006 and 2014, research was primarily concerned with integrating basic sensors (accelerometers, gyroscopes) into wearable or home-based prototypes and applying simple threshold-based algorithms for SMS or

Table 1 Top 20 Articles with the Highest Total Citation Scores

Rank	Year	Authors	Title	Source Title	Cited by
1	2019	Yacchirema D.; de Puga J.S.; Palau C.; Esteve M. ⁹	Fall detection system for elderly people using IoT and ensemble machine learning algorithm	Personal and Ubiquitous Computing	146
2	2018	Yacchirema D.; De Puga J.S.; Palau C.; Esteve M. ⁸	Fall detection system for elderly people using IoT and Big Data	Procedia Computer Science	132
3	2006	Kang J.M.; Yoo T.; Kim H.C. ¹⁰	A wrist-worn integrated health monitoring instrument with a tele-reporting device for telemedicine and telecare	IEEE Transactions on Instrumentation and Measurement	112
4	2022	Virginia Anikwe C.; Friday Nweke H.; Chukwu Ikegwu A.; Adolphus Egwuonwu C.; Uchenna Onu F.; Rita Alo U.; Wah Teh Y. ¹¹	Mobile and wearable sensors for data-driven health monitoring system: State-of-the-art and future prospect	Expert Systems with Applications	104
5	2015	Garripoli C.; Mercuri M.; Karsmakers P.; Soh P.J.; Crupi G.; Vandenbosch G.A.E.; Pace C.; Leroux P.; Schreurs D. ¹²	Embedded DSP-based telehealth radar system for remote in-door fall detection	IEEE Journal of Biomedical and Health Informatics	97
6	2022	Ramasamy L.K.; Khan F.; Shah M.; Prasad B.VVS.; Iwendi C.; Biamba C. ¹³	Secure Smart Wearable Computing through Artificial Intelligence-Enabled Internet of Things and Cyber-Physical Systems for Health Monitoring	Sensors	83
7	2019	Luna-Perejón F.; Domínguez-Morales M.J.; Civit-Balcells A. ¹⁴	Wearable fall detector using recurrent neural networks	Sensors (Switzerland)	74
8	2019	Kotronis C.; Routis I.; Politi E.; Nikolaidou M.; Dimitrakopoulos G.; Anagnostopoulos D.; Amira A.; Bensaali F.; Djelouat H. ¹⁵	Evaluating Internet of Medical Things (IoMT)-Based Systems from a Human-Centric Perspective	Internet of Things (Netherlands)	43
9	2022	Issa M.E.; Helm A.M.; Al-Qaness M. A.A.; Dahou A.; Elaziz M.A.; Damaševičius R. ¹⁶	Human Activity Recognition Based on Embedded Sensor Data Fusion for the Internet of Healthcare Things	Healthcare (Switzerland)	35
10	2018	Gochoo M.; Tan T.-H.; Batjargal T.; Seredin O.; Huang S.-C. ¹⁷	Device-Free Non-Privacy Invasive Indoor Human Posture Recognition Using Low-Resolution Infrared Sensor-Based Wireless Sensor Networks and DCNN	Proceedings - 2018 IEEE International Conference on Systems, Man, and Cybernetics, SMC 2018	29

(Continued)

Table 1 (Continued).

Rank	Year	Authors	Title	Source Title	Cited by
11	2019	Wayan Wiprayoga Wisesa I.; Mahardika G. ¹⁸	Fall detection algorithm based on accelerometer and gyroscope sensor data using Recurrent Neural Networks	IOP Conference Series: Earth and Environmental Science	27
12	2019	Shahiduzzaman K.M.; Hei X.; Guo C.; Cheng W. ¹⁹	Enhancing Fall Detection for Elderly with Smart Helmet in a Cloud-Network-Edge Architecture	2019 IEEE International Conference on Consumer Electronics - Taiwan, ICCE-TW 2019	26
13	2016	Chandel V.; Sinharay A.; Ahmed N.; Ghose A. ²⁰	Exploiting IMU sensors for IoT enabled health monitoring	IoTHealth 2016 - Proceedings of the 1st Workshop on IoT-Enabled Healthcare and Wellness Technologies and Systems, co-located with MobiSys 2016	24
14	2017	Balaguera H.U.; Wise D.; Ng C.Y.; Tso H.-W.; Chiang W.-L.; Hutchinson A.M.; Galvin T.; Hilborne L.; Hoffman C.; Huang C.-C.; Wang C.J. ²¹	Using a Medical Intranet of Things System to Prevent Bed Falls in an Acute Care Hospital: A Pilot Study	Journal of Medical Internet Research	23
15	2018	Torres G.G.; Bayan Henriques R.V.; Pereira C.E.; Müller I. ²²	An EnOcean Wearable Device with Fall Detection Algorithm Integrated with a Smart Home System		22
16	2022	Zhang Y.; Zheng X.; Liang W.; Zhang S.; Yuan X. ²³	Visual Surveillance for Human Fall Detection in Healthcare IoT	IEEE Multimedia	20
17	2017	Kolakowski J.; Djaja-Josko V.; Kolakowski M. ²⁴	UWB monitoring system for AAL applications	Sensors (Switzerland)	19
18	2020	Cai W.-Y.; Guo J.-H.; Zhang M.-Y.; Ruan Z.-X.; Zheng X.-C.; Lv S.-S. ²⁵	GBDT-Based Fall Detection with Comprehensive Data from Posture Sensor and Human Skeleton Extraction	Journal of Healthcare Engineering	18
19	2017	Joshi N.B.; Nalbalwar S.L. ²⁶	A fall detection and alert system for an elderly using computer vision and Internet of Things	RTEICT 2017–2nd IEEE International Conference on Recent Trends in Electronics, Information and Communication Technology, Proceedings	18
20	2011	Losardo A.; Bianchi V.; Grossi F.; Matrella G.; De Munari I.; Ciampolini P. ²⁷	Web-enabled home assistive tools	Assistive Technology Research Series	16

teleported fall alerts. After 2015, there was a marked acceleration in both publication volume and technological maturity: studies began leveraging IoT architectures and cloud computing for real-time monitoring and data storage, and adopted machine-learning models such as decision trees and big-data analytics to improve detection accuracy. The peak citation years of 2018–2019 led by Yacchirema et al (Escuela Politécnica Nacional, Ecuador) and Palau et al (Universitat Politècnica de València, Spain)⁸ highlighted advances in wearable, ML-driven systems that fuse multiple sensors and distribute processing between edge devices and the cloud. Geographically, Spain and Ecuador have produced the most impactful contributions, with notable work also emerging from the United States, South Korea, and China on

Table 2 Methodological Approaches and Their Evolution

Period	Dominant Methods/Technologies	Key Trends/Findings
2006–2014	Embedded sensors, threshold-based algorithms, tele-reporting	Early feasibility, integration of basic sensors, SMS/tele-reporting, initial wearable prototypes
2015–2018	IoT, cloud computing, decision trees, big data	Real-time monitoring, data analytics, cloud-based services, improved accuracy with ML models
2019–2022	Ensemble ML, deep learning (RNN, DCNN), data fusion	High-accuracy fall detection, edge/cloud processing, sensor fusion, vision-based and privacy-preserving tech
2022–present	AI-enabled cyber-physical systems, secure architectures	Secure, scalable, human-centric systems, integration with smart homes, focus on usability and privacy

telemedicine, embedded radar, and AI-enabled platforms. Methodologically in Table 2, the field transitioned from rule-based detection to ensemble machine learning and deep-learning approaches (eg, random forests, RNNs, DCNNs) around 2019–2022, achieving higher accuracy through sensor fusion and vision-based, privacy-preserving techniques. Since 2022, focus has shifted toward secure, AI-enabled cyber-physical systems that emphasize human-centric design, clinical workflow integration, usability studies, and scalability within smart-home environments. Overall, the evolution from simple, data-limited prototypes to sophisticated, adaptive, and secure IoHT solutions reflects broader trends in digital health and AI for aging populations.

The analysis of document types indicates that conference papers dominate the field, followed by journal articles (Figure 2).

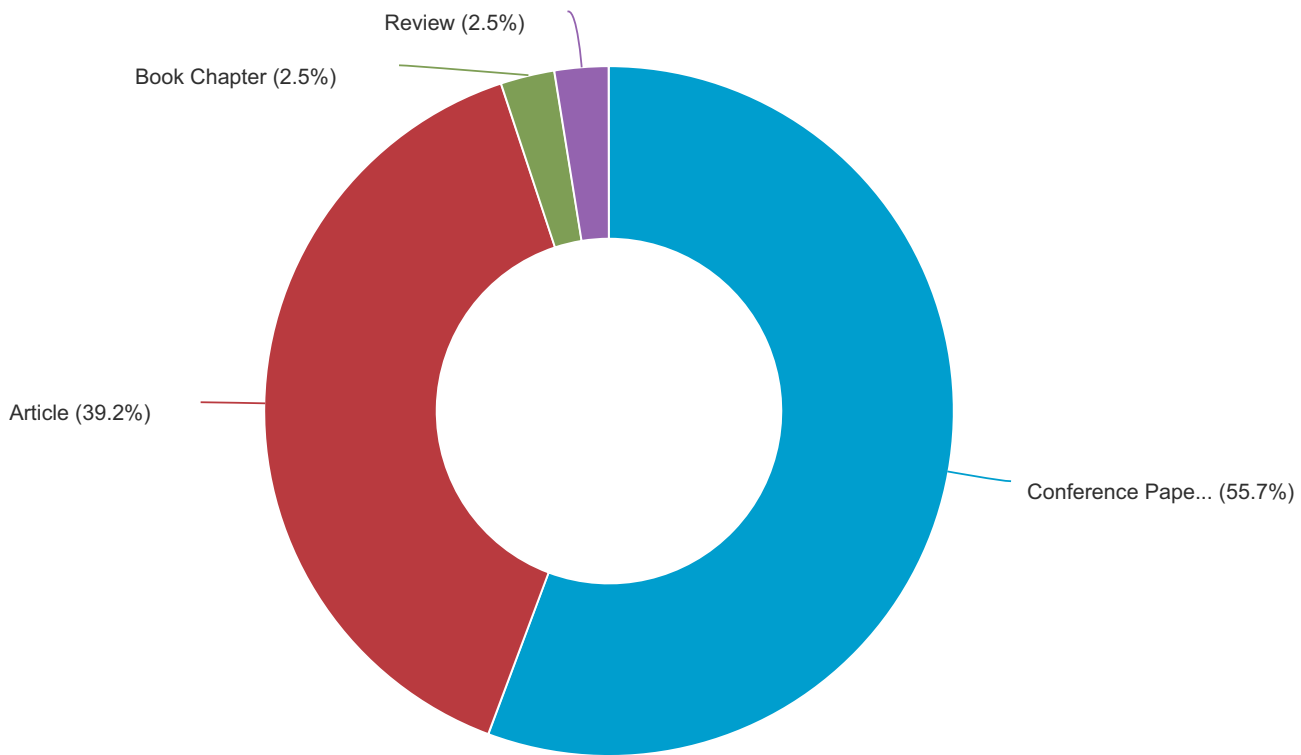


Figure 2 The distribution of document types from 2006 to 2025.
Notes: Figure 2 the distribution of document types retrieved from Scopus for our fall-detection IoHT corpus. Conference papers constitute the majority of outputs (55.7%), reflecting the community's preference for rapid dissemination of preliminary results and emerging prototypes in highly iterative engineering and computing venues. Journal articles follow at 39.2%, indicating that a substantial portion of work has undergone more extensive peer review and formal presentation of mature systems or comprehensive evaluations. Book chapters and review articles each account for only 2.5% of the total, suggesting that integrative syntheses and theoretical expositions remain relatively scarce in this domain. Together, these proportions underscore a research landscape driven by fast-moving, implementation-oriented studies, with fewer dedicated efforts toward retrospective analysis or broad, conceptual overviews.

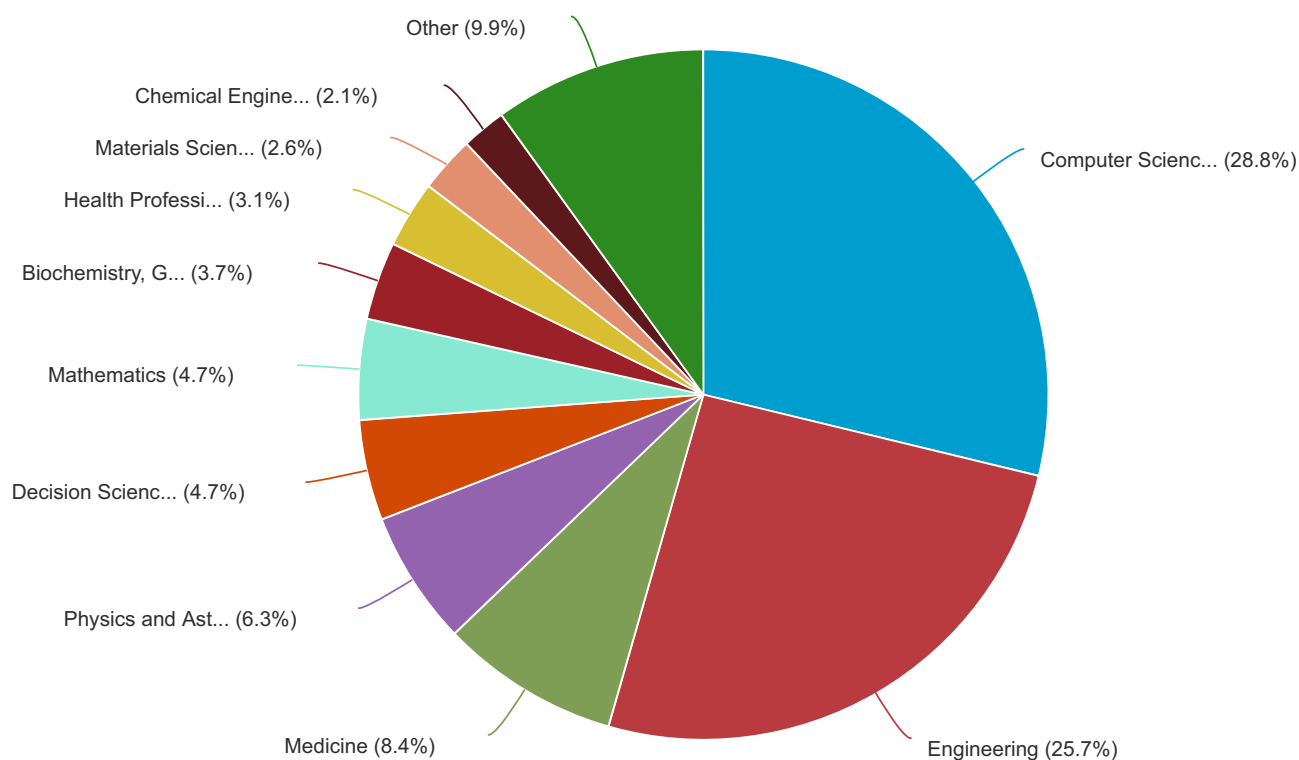


Figure 3 The Document by subject from 2006 to 2025.

Notes: Figure 3 presents the document according to Scopus subject categories. Computer Science leads with 28.8% of documents, closely followed by Engineering at 25.7%, together accounting for over half of all high-impact outputs. Medicine contributes 8.4% of the papers, reflecting clinical interest in fall-detection technologies, while Physics and Astronomy (6.3%), Decision Sciences (4.7%), and Mathematics (4.7%) each play a more modest role, indicative of analytical and modeling efforts underpinning algorithm development. Smaller slices in Biochemistry, Genetics & Molecular Biology (3.7%), Health Professions (3.1%), Materials Science (2.6%), and Chemical Engineering (2.1%) highlight the involvement of sensor materials, molecular-level biosensing concepts, and applied healthcare expertise. The “Other” category (9.9%) captures remaining interdisciplinary areas, underscoring that while fall-detection research is grounded primarily in computing and engineering, it nevertheless draws on a broad array of fields to address sensor design, data analysis, and clinical integration.

In terms of subject areas, Computer Science and Engineering account for more than half of publications (Figure 3).

India, China, and the United States are the top contributors, highlighting their leadership in this domain (Figure 4).

The distribution of top-cited authors shows a collaborative rather than single-author dominance (Figure 5).

High-impact outputs are distributed across diverse institutions worldwide (Figure 6).

Keyword co-occurrence mapping reveals four main clusters, including ambient intelligence and networked wearables (Figure 7).

The overlay visualization shows the chronological evolution from hardware prototyping to AI-driven systems (Figure 8).

The density visualization highlights fall detection, accelerometers, and health care as the most central themes (Figure 9).

Discussion

Evolution of Research Output: Volume and Impact

The field of embedded Internet of Health Things (IoHT) fall detection for the elderly has experienced significant growth and transformation over the past two decades. Early research (2006–2012) was sporadic, with annual publication counts rarely exceeding three documents. This period was characterized by foundational work on integrating basic sensors (accelerometers, gyroscopes) into wearable or home-based prototypes, primarily utilizing simple threshold-based algorithms for fall alerts. These early systems, while innovative, suffered from high false alarm rates and limited sensitivity.

A marked acceleration began in 2018, with publication counts rising sharply and peaking at twelve documents in 2024. This surge reflects both increased research interest and technological maturation in the field. The rapid growth over

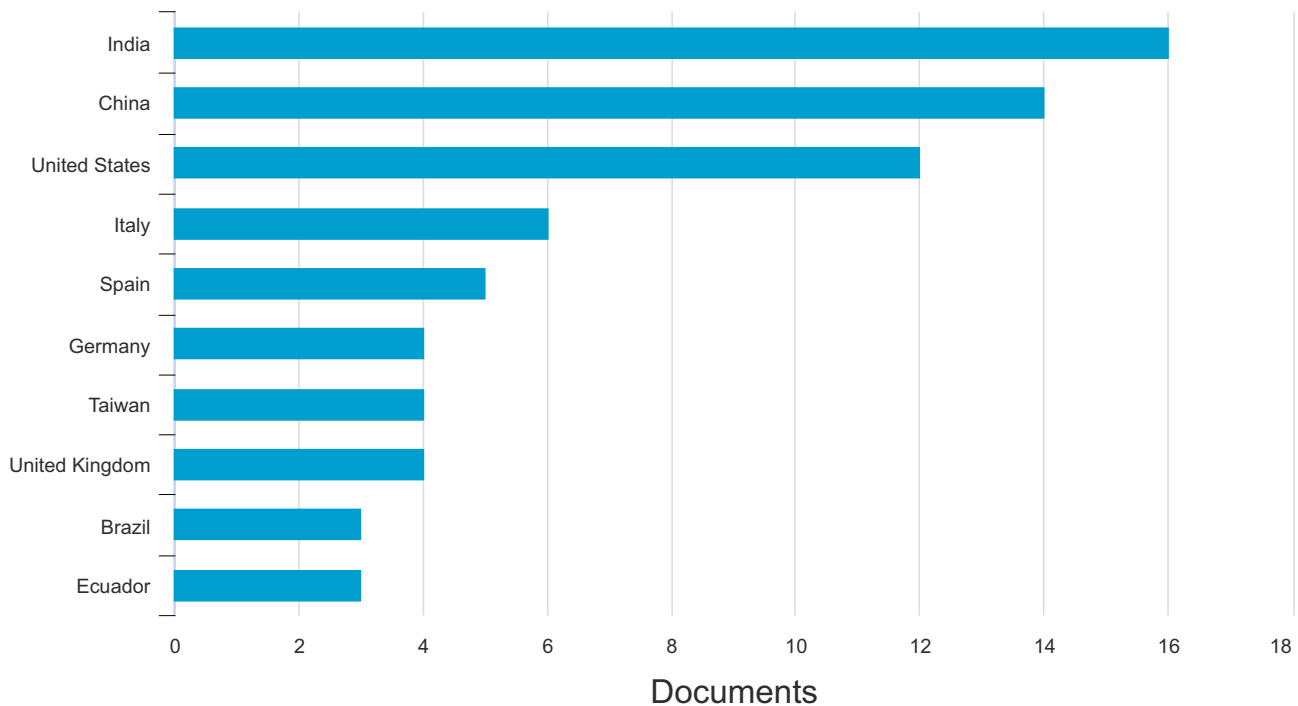


Figure 4 The Document by country or territory from 2006 to 2025.
Notes: Figure 4 illustrates the distribution of documents by country or territory based on Scopus data. India leads with the highest number of publications, followed closely by China and the United States, each contributing a significant volume of research outputs. These three countries collectively dominate the publication landscape, indicating their strong research engagement in the relevant field. Italy, Spain, Germany, Taiwan, and the United Kingdom follow, each producing a moderate number of documents. Brazil and Ecuador contribute fewer publications compared to other countries, but their presence still reflects a growing global interest. Overall, the data suggests that research activities are concentrated in a few leading countries, particularly in Asia, North America, and Europe, emphasizing their pivotal role in advancing the scholarly discourse in this domain.

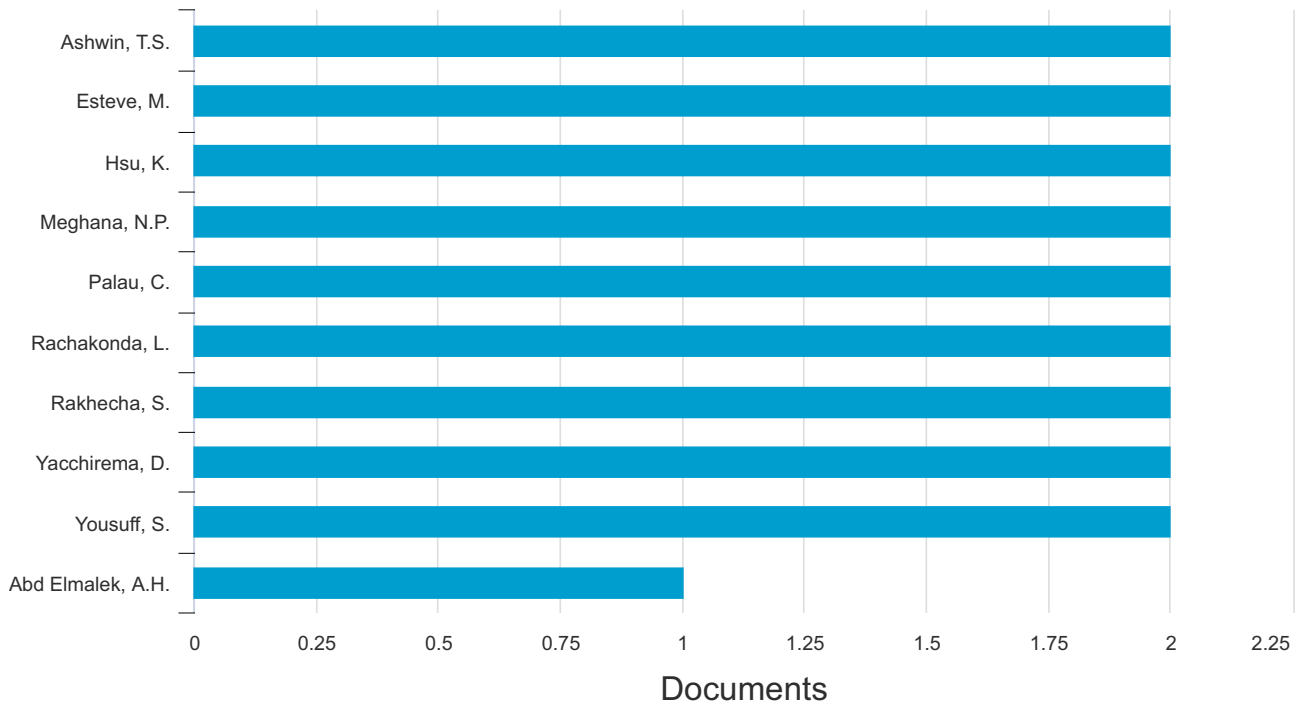


Figure 5 The Document by author from 2006 to 2025.
Notes: Figure 5 shows the distribution of top-cited fall-detection publications by author. Nine researchers—Ashwin T.S., Esteve M., Hsu K., Meghana N.P., Palau C., Rachakonda L., Rakhecha S., Yacchirema D., and Yousuff S.—each appear as co-authors on two of the twenty most-cited papers, making them the most prolific contributors in this elite group. In contrast, Abd Elmalek A.H. is represented by a single article. The fact that no individual author exceeds two high-impact publications suggests that progress in embedded IoT fall detection is driven by a distributed network of collaborators rather than by any single dominant figure.

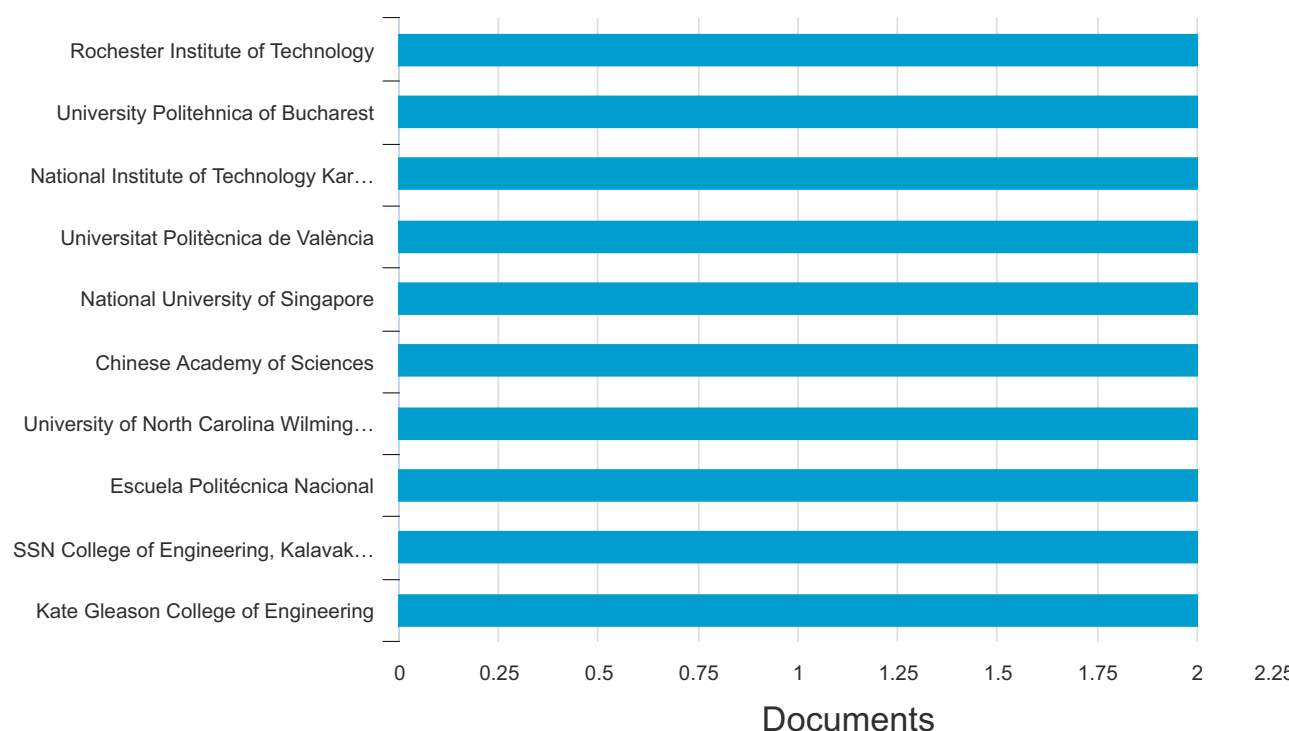


Figure 6 The Document by affiliation from 2006 to 2025.

Notes: Figure 6 shows that ten different institutions, with no single affiliation contributing more than this. These institutions span North America (Rochester Institute of Technology; University of North Carolina Wilmington; Kate Gleason College of Engineering), Europe (University Politehnica of Bucharest; Universitat Politècnica de València; Escuela Politécnica Nacional), and Asia (National Institute of Technology Karnataka; National University of Singapore; SSN College of Engineering, Kalavakkam; Chinese Academy of Sciences). The even distribution of high-impact outputs across a diverse set of technical universities underscores the field's collaborative and multi-regional character, suggesting that advances in fall-detection IoHT are driven by a broad network of engineering and computer-science research centres rather than being concentrated within a single "hub."

the past five years underscores the urgency and relevance of fall detection as the global population ages and the prevalence of fall-related injuries rises.

Citation analysis of the top 20 most-cited articles reveals a parallel evolution in impact: highly cited works from 2018–2019, such as those by Yacchirema et al and Palau et al, introduced wearable, machine learning-driven systems that leveraged sensor fusion and distributed processing between edge devices and the cloud. These studies achieved high accuracy (often above 94%) and demonstrated the feasibility of real-time, IoHT-based fall detection with direct alerts to caregivers. The transition from simple, rule-based prototypes to sophisticated, adaptive, and secure IoHT solutions reflects broader trends in digital health and artificial intelligence for aging populations.

Geographic, Institutional, and Author Contributions

The research landscape is dominated by a few leading countries—India, China, and the United States—each making substantial contributions in terms of publication volume. These countries are followed by Italy, Spain, Germany, Taiwan, and the United Kingdom, reflecting a strong global interest, particularly in Asia, North America, and Europe. Notably, Spain and Ecuador have produced some of the most impactful (highly cited) contributions, especially in the development and clinical evaluation of wearable and IoT-based systems.

Institutional analysis shows that high-impact research is distributed across a diverse set of technical universities and research centers, with no single institution dominating the field. This suggests a collaborative, multi-regional character, with progress driven by networks of engineering and computer science centers rather than isolated "hubs".

At the author level, the most prolific contributors to the top-cited literature—such as Ashwin T.S., Esteve M., Hsu K., Meghana N.P., Palau C., Rachakonda L., Rakhecha S., Yacchirema D., and Yousuff S.—each appear as co-authors on two

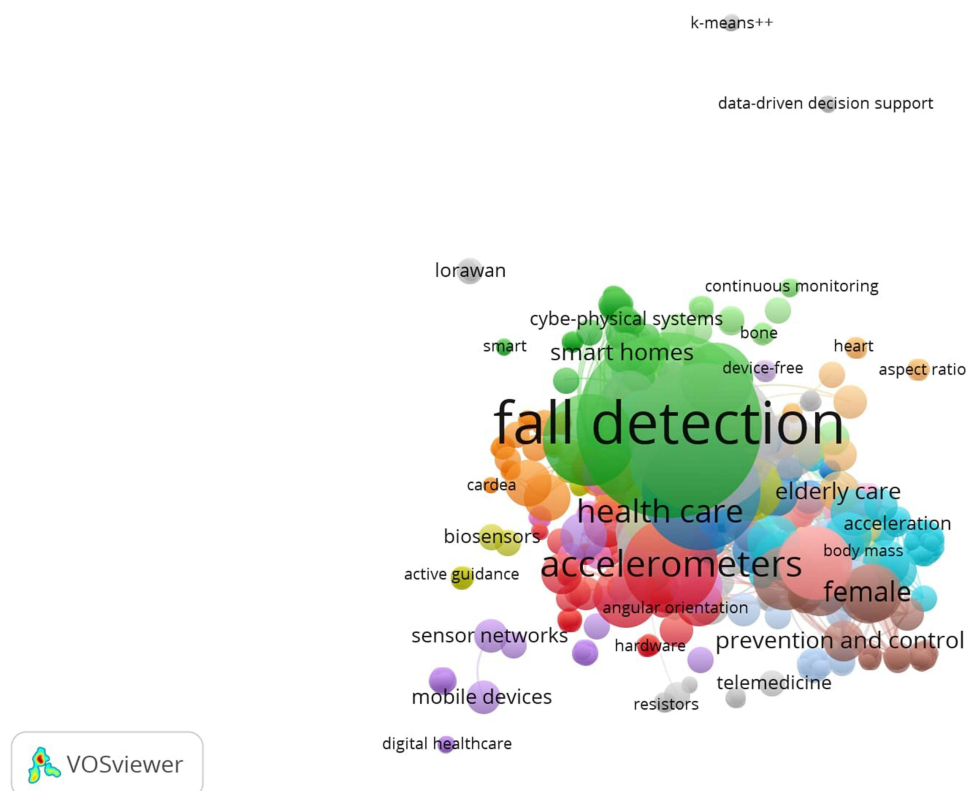


Figure 7 VOSviewer Keyword Co-Occurrence Network.

Notes: The VOSviewer-derived keyword co-occurrence network (Figure 7) positions “fall detection” at its core, reflected by its disproportionately large node and dense links to “accelerometers”, “elderly care”, and “prevention and control”, underscoring the field’s primary focus on sensor-based geriatric monitoring and risk mitigation. Four distinct thematic clusters emerge: an ambient intelligence cluster (green) highlighting “smart homes”, “continuous monitoring”, and “device-free” approaches for unobtrusive surveillance; an inertial sensor technology cluster (red) centered on hardware and signal-processing terms such as “angular orientation” and “accelerometer design”; a demographic influences cluster (light blue) emphasizing “female”, “body mass”, and “elderly care”, which reflects growing attention to how individual characteristics affect fall risk and detection accuracy; and a networked wearables cluster (purple) featuring “sensor networks”, “mobile devices”, and “digital healthcare”, indicative of efforts to integrate wearable systems with telemedicine infrastructures. Notably, machine-learning methods (eg, “k-means++” and “data-driven decision support”) and data privacy/security terms occupy peripheral positions, suggesting that advanced real-time decision-support frameworks and privacy-preserving mechanisms remain underexplored. Moreover, the absence of standardized dataset and evaluation protocol nodes highlights an urgent need for community consensus on shared benchmarks. Future research should therefore prioritize the integration of robust ML-driven decision support into real-time monitoring architectures, the development of device-free, privacy-centric solutions, and the establishment of unified datasets and evaluation standards, while tailoring algorithms to demographic and health profiles to enhance both sensitivity and clinical utility.

of the twenty most-cited papers. This indicates a distributed network of collaboration rather than dominance by any single figure.

Dominant Research Themes and Thematic Shifts

Keyword co-occurrence analysis identified four major thematic clusters in the field: ambient intelligence, emphasizing smart homes, continuous monitoring, and device-free surveillance; inertial sensor technology, focusing on hardware and signal-processing aspects such as angular orientation and accelerometer design; demographic influences, highlighting personalized approaches to fall risk and detection based on factors like gender, body mass, and elderly care; and networked wearables, centering on the integration of sensor networks, mobile devices, and digital health infrastructures. The thematic evolution over time demonstrates a clear progression, with early research (2010–2012) concentrating on infrastructure-level topics such as sensor networks and mobile devices, shifting between 2014–2018 toward applied sensor-based monitoring and healthcare applications, and, from 2020 onward, expanding to ambient intelligence, advanced machine learning techniques (eg, k-means++), and privacy-preserving strategies. Nonetheless, terms related to machine learning and privacy/security remain relatively underrepresented, revealing significant gaps and opportunities

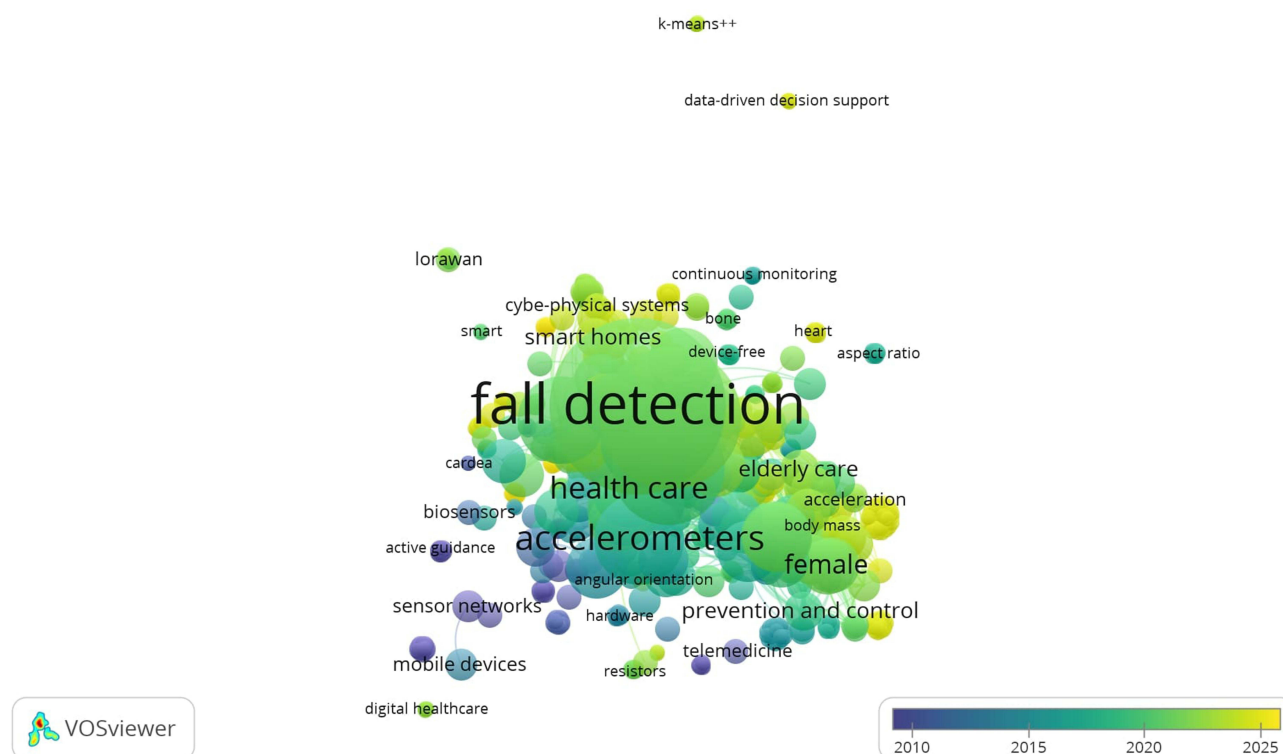


Figure 8 VOSviewer The overlay map.

Notes: The overlay map generated by VOSviewer (Figure 8) reveals a clear temporal progression in fall-detection research. Early themes (circa 2010–2012), shown in dark blue, focus on infrastructure-level topics such as “sensor networks”, “mobile devices”, and “hardware”, reflecting foundational work on connectivity and device design. Between 2014 and 2018, labeled in green to yellow-green hues, the focus shifts toward applied sensor-based monitoring—most notably “fall detection”, “accelerometers”, and “health care”—marking the field’s most prolific period of inertia-sensor innovations within clinical contexts. From approximately 2020 onward, terms appearing in bright yellow signal emerging frontiers: “device-free” and “smart homes” indicate a move toward ambient intelligence and unobtrusive environments, while “k-means++”, “data-driven decision support”, and “aspect ratio” point to the integration of advanced machine-learning algorithms and computer-vision techniques. This evolution underscores how the discipline has matured from hardware and network prototyping to sophisticated, privacy-conscious, real-time analytical systems.

for future research. Furthermore, the absence of standardized datasets and evaluation protocols underscores the urgent need for greater consensus on benchmarks and methodological frameworks within the research community.

Methodological Approaches and Their Evolution

The methodological landscape of embedded IoHT fall detection systems has evolved markedly over time. During the early period (2006–2014), research was largely dominated by threshold-based algorithms and simple sensor integrations, often paired with SMS or telemedicine alert systems. Between 2015 and 2019, the field saw the introduction of IoT architectures, cloud computing, and machine learning models such as decision trees, random forests, and ensemble learning to enhance detection accuracy and enable real-time monitoring. From 2019 to 2022, deep learning methods, including recurrent neural networks (RNNs) and deep convolutional neural networks (DCNNs), became widespread, accompanied by advancements in sensor fusion and the emergence of vision-based and privacy-preserving approaches. Most recently, the 2022–2025 period emphasizes the development of secure, AI-enabled cyber-physical systems, human-centric designs, clinical workflow integration, and usability studies, with growing attention to scalability, interoperability, and smart-home integration. Experimental studies consistently report high levels of accuracy, precision, sensitivity, and specificity, often exceeding 94%, particularly in systems utilizing ensemble machine learning and multimodal sensor fusion. Edge computing has also gained prominence for reducing latency and enhancing real-time performance, alongside a growing interest in integrating fall prediction and prevention features. The bibliometric analysis further highlights rapid technological advancement, driven by a globally collaborative research community, and an emerging focus on ambient intelligence, privacy-preserving monitoring, and context-aware machine learning. However, significant unmet

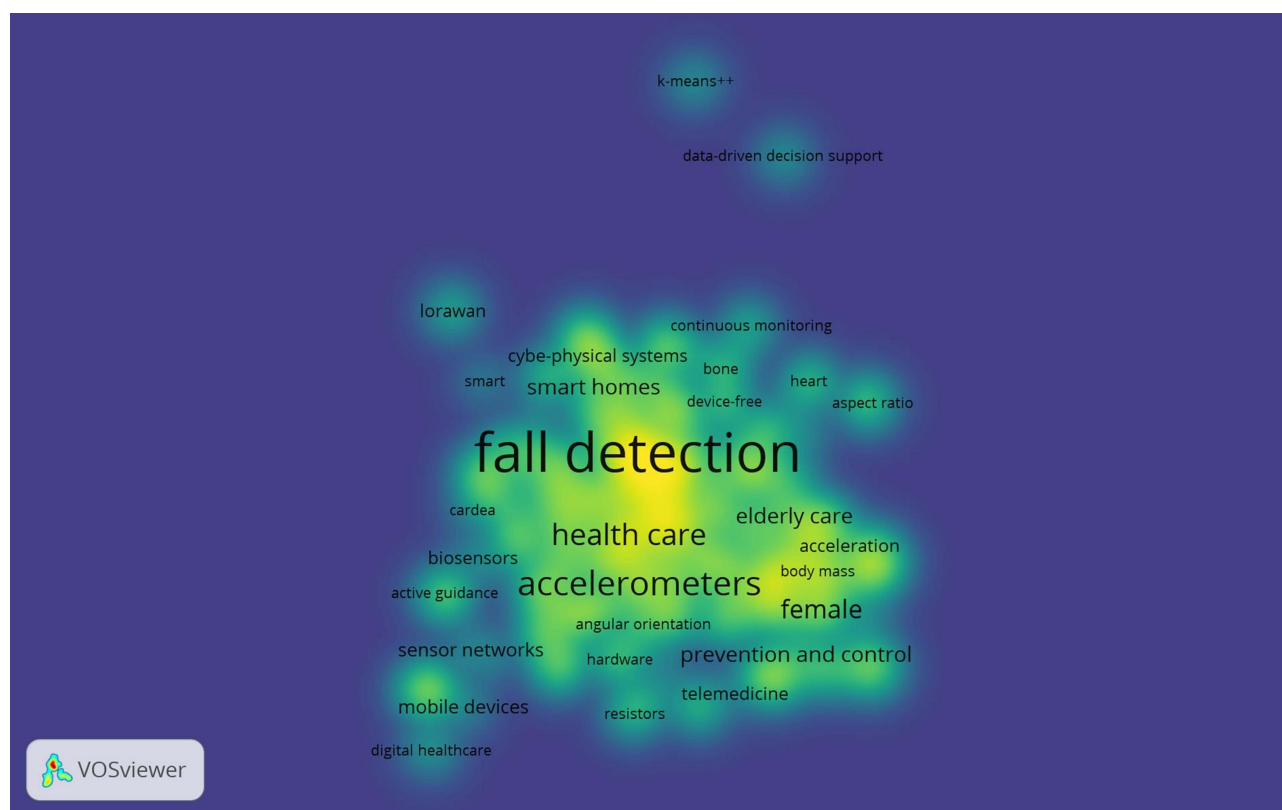


Figure 9 Density Visualization of Keyword Co-Occurrence.

Notes: The density visualization of keyword co-occurrence (Figure 9) underscores three core research foci in fall-detection literature: “fall detection”, “accelerometers”, and “health care”, each surrounded by bright yellow regions indicating the highest keyword frequency and co-occurrence strength, reflecting the central role of inertial sensors in clinical fall-monitoring studies. To the right, a secondary hotspot around “female”, “body mass”, and “elderly care” indicates substantial attention to demographic subgroups—particularly older women with varying anthropometric profiles. In contrast, topics such as “smart homes” and “continuous monitoring” appear in slightly cooler yellow-green hues, suggesting that ambient-intelligence applications and continuous surveillance systems are emerging but not yet as dominant as wearable-sensor research. Darker green areas around “mobile devices”, “sensor networks”, and “prevention and control” reveal significant yet peripheral thematic clusters. Machine-learning and decision-support terms like “k-means++” and “data-driven decision support” occupy blue zones of low density, highlighting their underrepresentation in current studies. Notably, privacy and data-security concepts are virtually absent, pointing to a critical gap and an opportunity for future work on privacy-preserving, intelligent fall-detection frameworks.

needs persist, including the development of standardized datasets, robust evaluation protocols, and comprehensive privacy/security frameworks, as well as the need for algorithms better tailored to diverse demographic and health profiles to ensure greater clinical applicability and user acceptance.

Limitations

This study is limited to the Scopus database without applying any inclusion or exclusion criteria. All document types including journal articles, conference papers, and books were included regardless of research method or language. As a result, the findings may reflect broad trends but lack selective filtering for study quality or relevance.

Conclusion

This bibliometric analysis demonstrates the rapid development of research on embedded IoHT fall detection for the elderly. In line with our research objectives, we observed a significant increase in publication volume particularly after 2018 indicating rising global interest. India, China, and the US lead in output, while Spain and Ecuador contribute highly cited works, highlighting influential authors and institutions. Thematic analysis revealed four major clusters—ambient intelligence, inertial sensors, personalized elderly care, and telemedicine linked wearables showing a shift from hardware centric systems to AI-driven, real time monitoring solutions. Methodologically, the field has progressed from threshold-

based models to machine learning, deep learning, and cloud/edge integration. Despite advancements, gaps remain in areas such as standardized datasets, privacy-preserving methods, and inclusive demographic modeling. These findings directly address the research questions posed, offering insight into the evolution, key contributors, dominant themes, and methodological trends in the field. Going forward, innovation must be coupled with clinical integration and user-centered design to realize the full potential of IoHT technologies. Bridging current gaps will be critical to developing scalable, effective fall detection systems for the aging population.

Ethical Approval

Ethical approval was not required as the study did not involve human participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Informed Consent

Informed consent was not required as the study did not involve.

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Disclosure

The authors report no conflicts of interest in this work.

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