Agile Software Engineering: A Comprehensive Bibliometric Analysis

Fadwa Saoiabi, Chaimae Elasri, Nassim Kharmoum, and Soumia Ziti

***Abstract*—This study conducts a bibliometric analysis of research literature in the field of Agile Software Engineering (ASE). Through systematic examination and quantitative analysis of academic publications, this research aims to elucidate the intellectual structure, trends, and dynamics within ASE research. By identifying influential works, prominent authors, and emerging topics, this analysis provides valuable insights into the evolution and current state of ASE. In addition, it sheds light on potential future directions and areas for further exploration, contributing to the advancement of knowledge and practice in agile software development methodologies. This study utilized the Web of Science database to gather bibliometric data on intelligent software development papers spanning from 1997 to 2024. Additionally, we used Biblioshiny from the R bibliomerix package, along with VOSViewer, to perform data analysis and extract insights, addressing research inquiries related to authors, articles, journals, organizations, and countries active in the domain of agile software development. Emphasizing scientific advancements and collaborative trends in scholarly research, our study serves as a blueprint for presenting global progress in agile software development. By gaining a comprehensive understanding of current research on agile methodologies in software development, this study provides valuable insights for software engineers, architects, and researchers in the field.**

***Index Terms*—software development, agile methodologies, user stories, bibliometrics, R, bibliometrix package, biblioshiny application, VOSviewer.**

I. Introduction

IN the fast-paced realm of software engineering [1], agile methodologies [2] have emerged as a transformative approach to software development, emphasizing flexibility, collaboration, and customer satisfaction. As organizations increasingly embrace agile practices to enhance productivity and adaptability, understanding the scholarly landscape surrounding agile software engineering becomes imperative. Bibliometric analysis [3] offers a systematic methodology to navigate and comprehend the vast body of literature pertaining to this dynamic field.

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Bibliometric analysis involves quantitatively analyzing publications, citations, and other bibliographic data to discern patterns, trends, and influential works within a specific domain. Applied to agile software engineering [4], bibliometric analysis provides invaluable insights into the evolution of agile methodologies, the dissemination of research, and the interdisciplinary connections shaping the field. By examining publication outputs, citation networks, and collaboration patterns, researchers can uncover the seminal contributions, emerging topics, and interdisciplinary intersections driving innovation in agile software engineering.

This introduction sets the stage for an in-depth exploration of bibliometric analysis in the context of agile software engineering. Through bibliometric lenses, researchers can unravel the underlying structure of knowledge, identify research gaps, and anticipate future developments in agile practices and methodologies. By harnessing the power of bibliometric analysis, scholars can not only advance theoretical understanding but also inform practical applications, thereby contributing to the continuous improvement of agile software engineering in real-world settings.

Well-conducted bibliometric analyses offer academics a comprehensive understanding of their respective fields, enabling them to pinpoint areas necessitating further research, inspire fresh investigative avenues, and validate their contributions to the discipline. Moreover, these studies serve as a solid foundation for advancing fields in innovative and crucial ways. Utilizing bibliometric software such as VOSviewer [5], Gephi [6] and Leximancer [7] facilitates practical data analysis, consequently driving heightened scholarly attention towards bibliometric analysis. It's important to highlight the role of scientific databases like Scopus and Web of Science [8], which have significantly simplified the acquisition of extensive bibliometric data.

The research questions we're trying to answer are:

Q1. What is the average number of citations per research document?

Q2. What are the best journals in the field?

Q3. What are the best authors in the field?

Q4. Which countries are contributing the most to this field?

Q5. Which countries are collaborating together?

Q6. How do countries, authors, and research documents correlate with each other?

Q7. What is the annual research growth rate?

Q8. What are the top institutions and authors contributing in the field?

Q9. What papers have the biggest impact in the field (citations)?

Q10. Which organizations or institutions tend to collaborate with each other?

Q11. What are the trending topics in the field (keywords)?

Analyzing these research questions offers valuable insights into the long-term impact, productivity, and evolving trends within research. Through examining the citation impact of individual researchers, articles, or journals, scholars can pinpoint the most influential contributions within a given field. This understanding can then guide funding allocations and shape future research trajectories. Moreover, delving into collaboration patterns among authors and organizations facilitates the identification of fruitful partnerships, enhancing the effectiveness of research endeavors. These inquiries also shed light on emerging research domains and areas warranting increased attention or investment. Furthermore, they offer a glimpse into the productivity and impact of research across various regions and countries, thereby informing strategic research policies and investment decisions [9].

This study provides valuable theoretical and practical insights into agile software development. Theoretical contributions include the exploration of research trends, including popular topics, highly cited articles and authors, and influential journals. These findings offer researchers the opportunity to pinpoint gaps in the literature and steer future research endeavors. Additionally, the study introduces a novel bibliometric framework tailored specifically for agile software development research, with the potential for broader application in identifying trends and gaps across various fields. Furthermore, it delves into the intricate networks of collaboration among authors, institutions, and countries, facilitating cross-regional collaborations and knowledge sharing. On a practical level, the study identifies key research areas, offering guidance for scholars seeking to prioritize their research efforts. Moreover, it sheds light on influential researchers and institutions, providing valuable cues for potential collaboration opportunities within the field [10].

The remainder of this article follows a structured outline. Section II provides an overview of related works within the studied field. Following this, section III outlines the steps taken for data collection and the query employed. In section IV, the research methodology employed is elucidated. Section V presents the findings of the study, while section VI engages in a discussion of these results. Lastly, section VII presents the conclusion drawn from the study.

II. Related Works

Software engineering has undergone substantial growth, drawing significant interest from the scientific community. Garousi & Mäntylä's (2016) [11] comprehensive study stands out as a pivotal exploration, providing insights into predominant authors, key research topics, and actively contributing countries in the field. The study revealed an annual publication of approximately 6000-7000 papers, with the United States, China, and the United Kingdom leading in contributions. Notably, the authors highlighted crucial research themes in software engineering, including web services, mobile and cloud computing, industrial/case studies, source code, and test generation, reflecting the dynamic and evolving nature of the discipline.

Most studies contribute to focusing their analysis on a subdomain of software engineering. In this area, four studies that adopt a bibliometric approach deserve particular attention. Adams & Pinto (2005) [12] delved into the significance attributed to risk management in software engineering, revealing a lack of scientific studies on the subject and advocating for additional concentrated research in this area. Tavares et al. (2017) [13] conducted a parallel study twelve years later, reaffirming the dearth of scientific exploration on risk management in scrum projects. Karg et al. (2011) [14] undertook a systematic review of software quality costs, finding that the majority of articles in the field lacked empirical validation, particularly across multiple companies, and highlighted the underexplored realm of prevention costs. In another bibliometric analysis, Freitas & Souza (2011) [15] scrutinized search-based software engineering, covering 740 publications and noting a substantial 20% growth in this research domain between 2001 and 2010 across dimensions such as publication, sources, authorship, and collaboration.

Gustavsson (2016) [16] conducted an analysis from a reverse standpoint, aiming to illustrate the applicability and adaptability of agile principles from software development to other domains. The study's results affirm the advantageous impact of agile principles on teamwork, customer interaction, productivity, and flexibility across diverse fields, including library management and strategic management. Furthermore, Christie et al. (2012) [17] undertook a literature review on prototyping strategies, categorizing them into distinct groups with shared characteristics. The findings underscore the widespread utilization of prototyping strategies in various sectors, encompassing perspectives from both business and engineering.

Agile software development methodologies currently stand as one of the most pertinent and emerging topics within the software engineering domain. Numerous studies have systematically organized the primary research directions in this field. Dyba & Dingsøyr (2008) [18] identified four overarching themes: (i) introduction and adoption, (ii) human and social factors, (iii) perceptions of agile methods, and (iv) comparative studies. Their examination also delves into the benefits and limitations associated with agile software methods. In a comprehensive overview spanning the decade from 2002 to 2012, Dingsøyr et al. (2012) [19] concluded that agile software development remains a highly dynamic and prolific research area, evidenced by a substantial volume of publications in scientific journals and international conferences. Moreover, their study highlighted the United States, Canada and Germany as the three most influential countries in terms of publications within this domain.

"Agile" is seen today as more than just a methodology in the software industry, it is now regarded as a work philosophy necessitating substantial changes in team and people management. Sheuly's (2013) [20] systematic literature review on Agile Project Management (APM) revealed a predominant focus on how practitioners implement agile methods in this field. The study identified various APM methods, including Scrum, extreme programming (XP), Crystal Clear method, DSDM, and lean programming. Mishra et al. (2015) [21] conducted a comparative analysis of popular agile methodologies like Scrum, XP, and Kanban. Lechler & Yang (2017) [22] delved into the role of project management in agile software development, concluding that the academic discourse on agility has been predominantly unidirectional, often examining challenges posed by agile methodologies in project management. They emphasized a need for more analysis on how different project management techniques can be effectively applied within agile methodologies.

Hossain et al. (2009) [23] concentrated their analysis on the implementation of Scrum in Global Software Development (GSD) projects, examining 20 primary research papers in this area. Their conclusion highlighted that scrum practices might not be entirely suitable for supporting globally distributed software development teams, where substantial challenges often arise in terms of communication, coordination, and collaboration processes. In a related study, Rizvi et al. (2015) [24] investigated the reasons and conditions that influence the adoption of agile distributed software engineering practices. The findings revealed challenges faced by teams, including time zone disparities, limited knowledge of resources, and insufficient infrastructure. To facilitate work in geographically distributed teams, the study suggested establishing a robust communication infrastructure, encouraging both formal and informal communications among team members, and implementing effective tools to enhance collaboration.

III. Data Collection

Bibliometric analysis serves as a widely accepted and precise method for examining extensive sets of scientific data. This approach allows for the identification of emerging fields and a comprehensive understanding of the evolution within a specific field [25]. The use of bibliometric software further streamlines the sorting and analysis of large datasets derived from studies conducted over a defined time frame. In contrast to systematic literature reviews, which often rely on qualitative methods and may be susceptible to interpretation bias due to diverse academic backgrounds among researchers, systematic reviews and bibliometric analyses prioritize statistical approaches, thereby minimizing the potential for bias [25].

Numerous databases are available for extracting literature data, such as Web of Science (WoS), Scopus, PubMed, Lens, and Google Scholar, each serving specific purposes with unique features. Google Scholar generally provides broader coverage across various disciplines, whereas Web of Science and Scopus offer comparable results [26]. Web of Science stands out for its diverse methods influencing search outcomes, encompassing general, cited reference, and advanced search functions. All three databases enable the tracking, counting, processing, and analysis of cited references [27].

With almost 10,000 journals encompassed, Web of Science incorporates seven distinct citation databases, gathering information from book series, conferences, journals, reports, and books [28]. Recognized as one of the most comprehensive databases, WoS provides access to articles from high-quality research literature [29]. It boasts an extensive collection of esteemed journals and top-notch publications that have undergone prior evaluation by experts in their respective fields [30], positioning it as a reliable source for research articles [31]. Hence, Web of Science was chosen for this study. The Web of Science core collection was specifically utilized due to its comprehensive coverage across major scientific disciplines and inclusion of numerous high-impact journals, ensuring a thorough representation of literature on intelligent software development [30], [32]. The uniform indexing and citation metrics applied to all journals in the core collection facilitate standardized and dependable comparisons among articles, authors, and journals, leading to valid and reliable bibliometric analysis [33].

The selected papers for this study have been disseminated by esteemed and widely recognized publishers, such as MDPI, IEEE, Elsevier, and Springer. These publishers are renowned for their significant contributions to scientific research and are frequently affiliated with the publication of top-notch papers across diverse fields, encompassing computer science, engineering, medicine, and beyond.

Figure 1 demonstrates the search strategy applied in this research.

The selected keywords were identified through an extensive search encompassing papers on software development and agile methodology. The term **"software development"** acts as a broad category, covering various related keywords such as "software engineering," "software testing," "programming," "software quality," and "software analysis." Similarly, the term **"agile methodology"** serves as an overarching category for keywords such as "agile" and "agile project management." Additionally, the keyword **"user stories"** functions as a comprehensive umbrella, encompassing related terms like "user story," "planning," "story mapping," and "story map."

Initially, a search was conducted using keywords related to the realm of software development, agile methodology, and user stories, employing the "AND" operator across all fields of the Web of Science core collection. This yielded a total of **772 documents**.

After eliminating all documents not written in English, which amounted to an exclusion of an additional **18 documents**, the final result set comprised **754 documents**.

The ultimate query appears as follows:

("agile" OR "agile methodology") AND ("software development" OR " software engineering" OR "software testing" OR "programming" OR "software design" OR "software maintenance" OR "software analysis" OR "software quality") AND ("user stories" OR "user story" OR "planning" OR " story mapping" OR "story map") (Topic)

IV. Research Method

A bibliometric study is a research methodology that employs statistical analysis of published literature to evaluate the impact of a specific field or body of work. In the context of software development, this approach involves the examination of various factors. These factors encompass the quantity and quality of publications related to software development, as well as an analysis of the authors and institutions contributing significantly to the field. Furthermore, a bibliometric study scrutinizes the citation patterns of software development papers to uncover trends and patterns in the research landscape. This type of research proves valuable for identifying critical research areas, gaining insight into the current state of the field, and identifying potential directions for future research.

We employed the Bibliometrix R Package (biblioshiny v4.0.1) software to conduct an extensive scientific mapping analysis following the extraction of the dataset from the

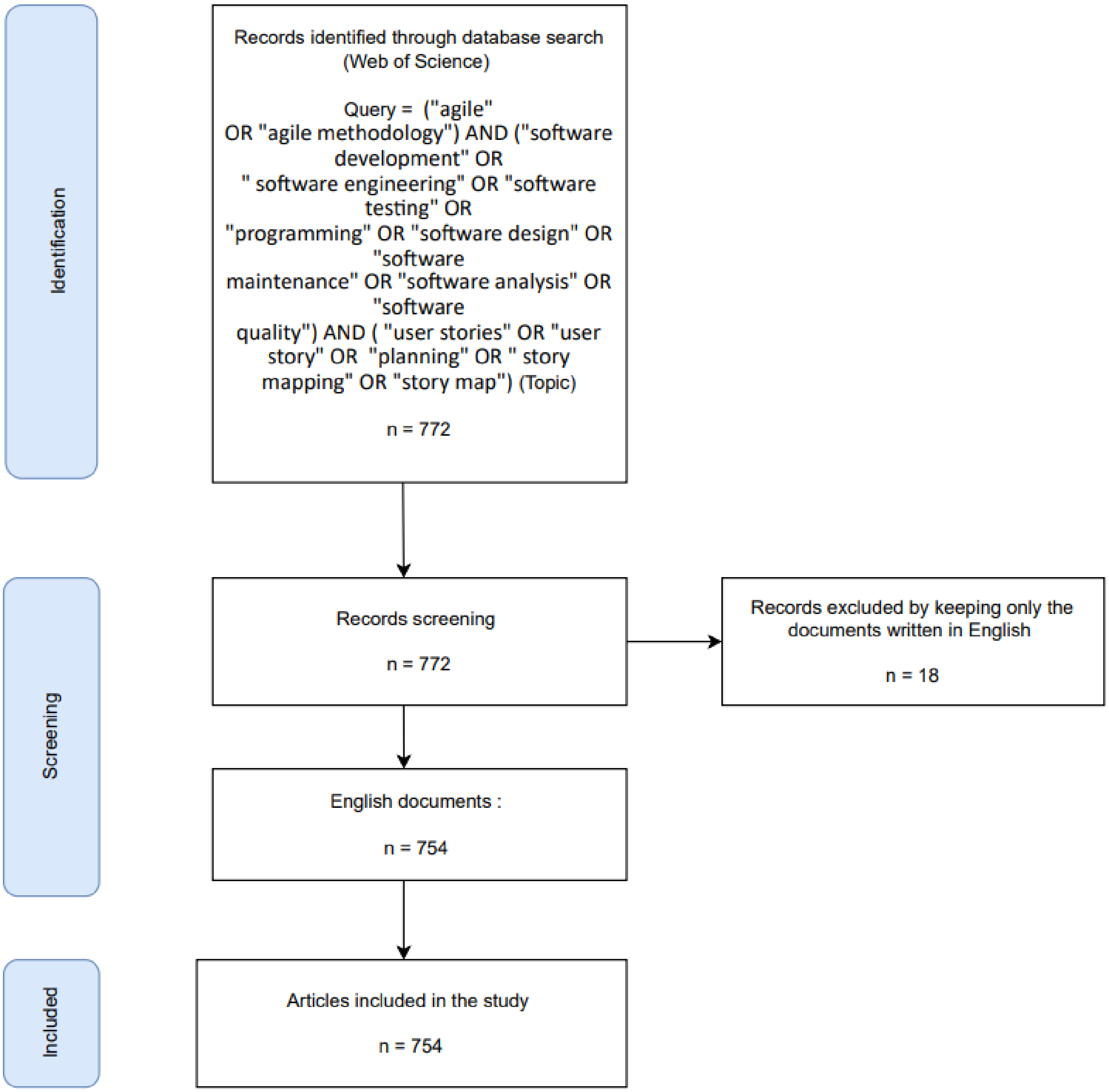

Fig. 1: Overview of the methodological search strategy.

WoS database [34]. This approach facilitated the generation of the majority of the graphs. Additionally, VOSviewer, a free software tool designed for creating and visualizing bibliometric maps [35], was used to generate the remaining graphs.

We initiated the process by presenting an overview of the dataset, encompassing the following items:

- **Main information:** Displayed in a table, this section highlights the fundamental traits of our dataset.
- **Scientific production:** Illustrated through a graph, this section depicts the annual scientific production within the studied field.
- **Citations per year:** Represented in a graph, this section visualizes the growth in citations over each year.
- **Relationship between countries, authors, and titles:** Presented as a Three-Field Plot, this section delineates the intricate relationship among countries, authors, and article titles in the analyzed domain.

The subsequent section of the findings focuses on science mapping, representing the concluding phase of a comprehensive domain analysis and visualization process. A science mapping project typically incorporates diverse components, including a body of scientific literature, an assemblage of metrics, indicators, scientometric tools for observation and analysis. These elements are commonly integrated to bring attention to significant trends and patterns, as well as to explore transformative scientific ideas that guide the analysis and interpretation of conceptual frameworks and cycles [36]. During this phase, our attention was directed towards the following aspects:

1) **The most successful and highly cited journals:**
   - A graphical representation showcasing the top ten most active journals, considering the quantity of articles published.
   - Another graph highlighting the top cited journals, determined by the quantity of citations they received;
2) **The most important organizations:**
   - An illustrative graph ranking the top 10 most prolific institutions based on the quantity of documents they generated.

3) **The most relevant authors:**
   - A graphical representation identifying the top 10 authors based on the volume of articles they created;
4) **Top developing nations according to corresponding authors:**
   - A graph spotlighting the top 10 countries with the highest article production, categorized into single-country or multi-country publications;
   - A graph presenting the top 10 most cited authors using data from the entire Web of Science database;
5) **The most globally cited documents:**
   - A graph featuring the top 10 most cited documents, utilizing all citations in the Web of Science database;
6) **The most frequent words:**
   - A graph and a word cloud illustrating the most commonly used words in the abstracts, titles, and keywords of the documents.
7) **Co-occurrence network of keywords:**
   - A graph depicting the relationships between keywords, categorized into smaller clusters;
8) **Collaboration world map and network:**
   - A graph and world map illustrating the relationships between countries in terms of collaboration;
9) **Organizations co-authorship:**
   - A graph displaying the network of collaborations between organizations;
10) **Authors co-citation network:**
   - A graph depicting the network of connections between authors based on co-citations;
11) **Journals co-citations network:**
   - A graph illustrating the network of correlations between journals based on co-citations.

The third section encompasses network analysis, a field rooted in network theory or graph theory. Network analysis involves exploring the properties of networks and understanding the interactions among their vertices and segments. Key metrics in network analysis include proximity and betweenness centrality indices. The centrality index serves as a representation of a vertex's social power, ranking each vertex based on its function and position in network communications [37]. In this segment of the study, our focus was on the following elements:

- **Thematic Map:** The creation of a network graph, termed a thematic map, using keywords and their interconnections. Each thematic map is labeled based on the keyword that appears most frequently in the connected topic [38].

- **Multiple Correspondence Analysis (MCA):** TA method for both visually and mathematically analyzing data, Multiple Correspondence Analysis (MCA) serves as a multidimensional analysis tool [39].

- **Correspondence Analysis (CA):** Correspondence analysis offers a visual means of understanding the relationships within a frequency table, specifically assessing connections between qualitative variables. It serves as an extension of principal component analysis, particularly for categorical data [40].

- **Multidimensional Scaling:** Similar to MCA and CA, multidimensional scaling is employed as a dimensionality reduction technique. This approach generates a map of the network under investigation using normalized data [34].

A comprehensive discussion of these elements will be presented in section 5 of this article. The research approach employed in this study is clearly summarized in figure 2:

V. Results

A. Overview

1) Main Information: Figure 3 & figure 4 present the primary findings concerning intelligent software development gleaned from the dataset sourced from the Web of Science database. It encompasses various aspects such as the research period, the journals and documents surveyed, the average citation count, references, and the yearly growth rate [41]. Crucial insights regarding content include author-provided keywords and the distinctive Keywords Plus feature exclusive to the Web of Science database. Additionally, the dataset contains information on document authorship, categorized into authors and authors of single-authored documents. Collaborative aspects are highlighted through metrics like the count of single-authored documents, the average number of authors per document, and the rate of international co-authorship. This general overview reflects not only the volume of academic output but also collaboration dynamics, suggesting that the field benefits from increasingly international and interdisciplinary research teams. These metrics provide a valuable baseline for deeper bibliometric exploration.

2) Annual Scientific Production : Figure 5 presents an overview of the annual scientific output in the field of software development research. The data demonstrates a clear upward trend, starting from 2 documents in 1997. The production grew steadily over the years, reflecting increased interest in the field. A peak of 80 articles was reached in 2019, followed by a slight decline, with 47 articles published in 2023, showcasing sustained academic engagement in this evolving domain.

3) Average Citation Per Year: Figure 6 shows the average yearly citations of documents. In 1997, the average stood at 1.6 citations per document, rising to 2.2 citations per document by 2015. However, in 2023, this average dropped to 0.4 citations per document, marking a growth rate of 20.56% annually.

4) Relationship between Countries, Authors, and Titles : The interplay between nations, authors, and document keywords in software development publications is visualized through a three-field plot [42]. Rectangles of varying colors represent the relevant components of the diagram [43]. The height of each rectangle corresponds to the cumulative relationships among the items it represents. The thickness of the links indicates the flow of information between various values. Figure 7 highlights that major research subjects in intelligent software development have been authored predominantly by individuals from the USA, Brazil, and Germany.

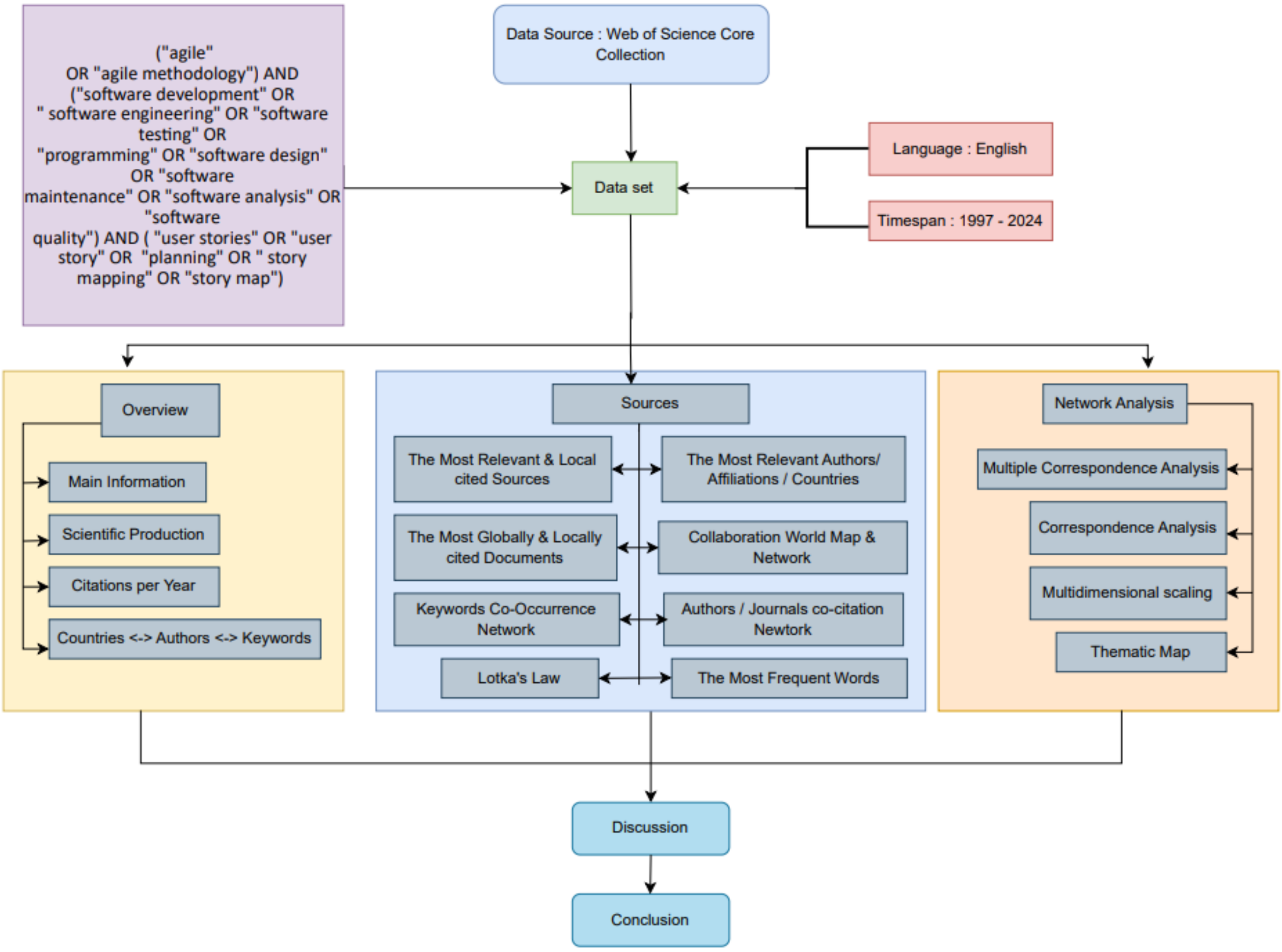

Fig. 2: Overview of the bibliometric analysis steps.

B. Sources

1) The Most Relevant & Local Cited Sources: Figure 8 enumerates the top ten primary sources, characterized by their abundance of papers on intelligent software development. The examination reveals that the "Information and Software Technology" journal [44] leads with 25 documents, followed by "IEEE Access" [45] and "Journal of Systems and Software," [46] each with 13 documents. Subsequently, the "Agile Processes in Software Engineering and Extrem" journal is noted with 8 documents.

Figure 9 presents the top 10 sources that have garnered the highest number of citations for their contributions to intelligent software development. According to bibliometric analysis, the "Information Software Technology" journal ranks as the most cited source with 628 citations, followed by the "Journal of Systems and Software" with 523 citations. Securing the third position is the "IEEE Software" journal, with 441 citations.

2) The Most Relevant Affiliations: The publication output of organizations or author affiliations involved in the advancement of intelligent software development was assessed, as depicted in figure 10. Topping the list are the "Blekinge Institute Technology" and the "University of Ljubljana" with 11 documents each, followed closely by "King Abdulaziz University" and "AALTO University" with 10 documents each.

This result underlines the geographical diversity of research contributions, with notable outputs from Europe and the Middle East. Such distribution may point to region-specific priorities in agile research, offering a potential avenue for comparative institutional analysis.

3) The Most Relevant Authors: Figure 11 presents the top 10 most influential authors in the field, out of a total of 2,062 contributors. Topping the list is "PAASIVAARA M," demonstrating prolificacy with 8 publications and a fractionalized value of 2.81. Following closely are "LASSENIUS C," "MAHNIC V," and "WAUTELET Y," each with 7 documents and fractionalized values of 1.81, 4.75, and 2.40 respectively. The recurring presence of these authors reflects a sustained engagement with agile research themes. Their contributions likely form key references for future studies, particularly in areas such as agile team dynamics, estimation techniques, and process improvement.

4) The Most Relevant Countries by Corresponding Authors: This study also considered the countries where the associated authors published their work concerning their contributions to intelligent software development, depicted in both figure 12 and figure 13. Leading the pack with 95 single-country publications, 10 multi-country publications, and the highest frequency of 0.139, the USA claimed the top spot. In terms of scientific productivity, the USA, Brazil, and India emerged as the top three countries globally.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1997:2024
Sources (Journals, Books, etc)	567
Documents	754
Annual Growth Rate %	-2.53
Document Average Age	7.59
Average citations per doc	9.402
References	18014
DOCUMENT CONTENTS	
Keywords Plus (ID)	516
Author's Keywords (DE)	1964
AUTHORS	
Authors	2062
Authors of single-authored docs	81
AUTHORS COLLABORATION	
Single-authored docs	95
Co-Authors per Doc	3.27
International co-authorships %	20.56
DOCUMENT TYPES	
article	270
article; early access	8
article; proceedings paper	8
meeting abstract	1
proceedings paper	441
review	26

Fig. 3: Main information.

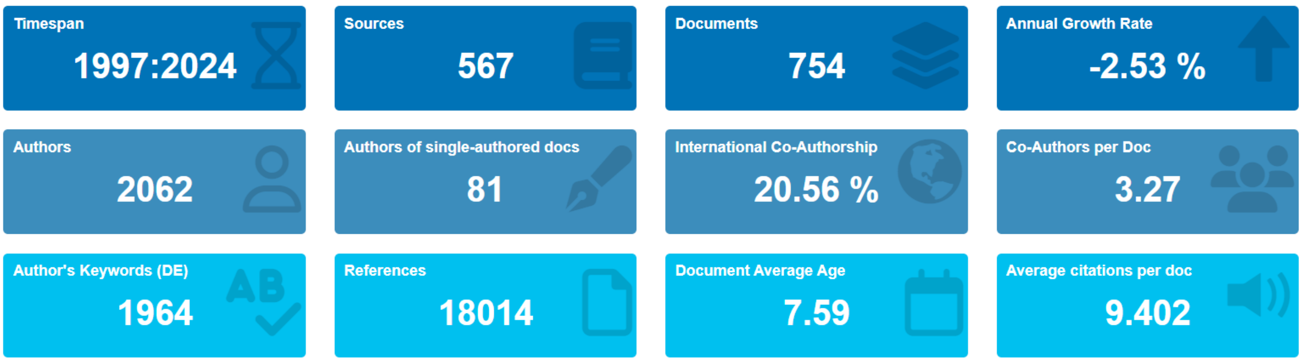

Fig. 4: Main information.

5) The Most Globally Cited Documents: Globally cited documents refer to the number of citations a particular document has garnered from other papers across the entire WoS core collection. Figure 14 illustrates the most referenced documents on a global scale. Topping the list is a paper authored by Serrador P, published in 2015 in the "International Journal of Project Management," with 257 citations. It is closely followed by a paper authored by Inayat I, published in 2015 in the "Computers in Human Behavior" journal, which has received 228 citations.

The high citation counts indicate that these studies have had a significant impact in shaping theoretical and practical approaches to agile software development. Their continued influence suggests that they are key anchor points in the scholarly dialogue around agile methodologies.

6) The Most Locally Cited Documents : The count of citations a specific document receives from other papers within the studied dataset is termed its local citation count, focusing here on the realm of intelligent software development. Figure 15 displays the most frequently cited documents within this local context. Leading the list is the paper titled "On using planning poker for estimating user stories," [47] authored by Mahnic V in 2012, with 32 citations.
This result highlights how certain methodological contributions — particularly around estimation and agile planning — have gained traction within the core research community. It underscores the relevance of practical, process-focused research to the academic discourse.

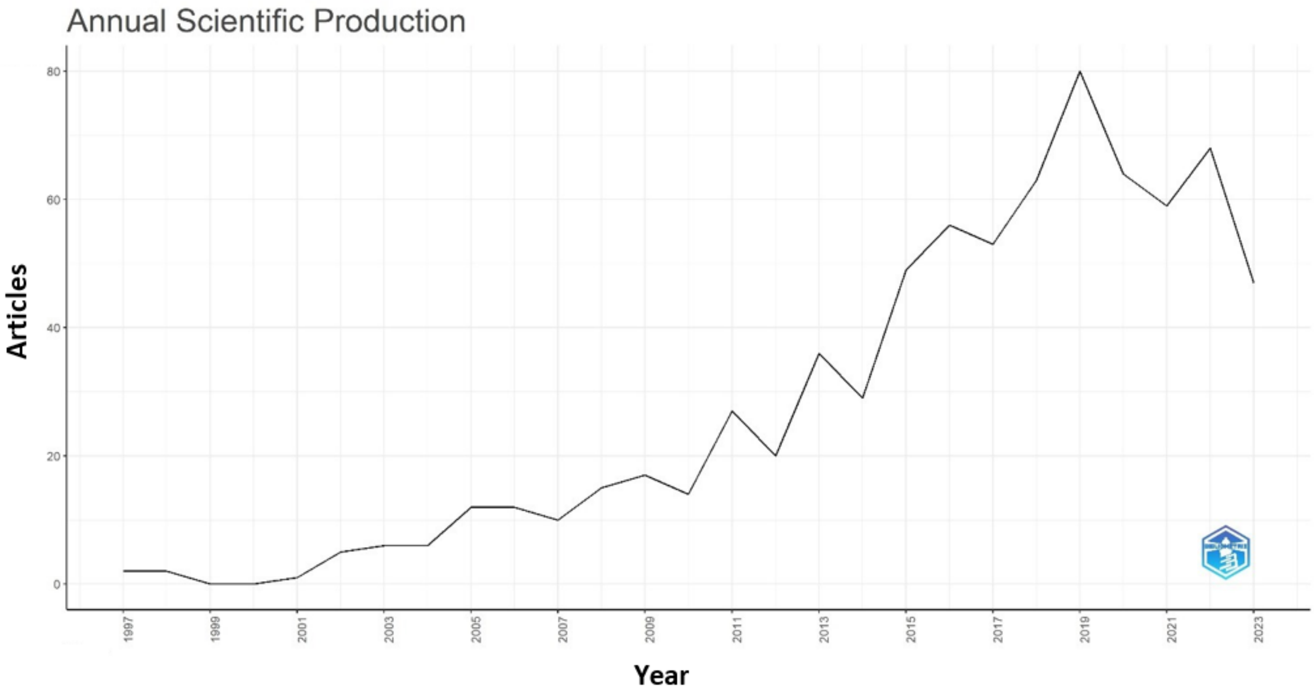

Fig. 5: The annual scientific production in the field of intelligent software development.

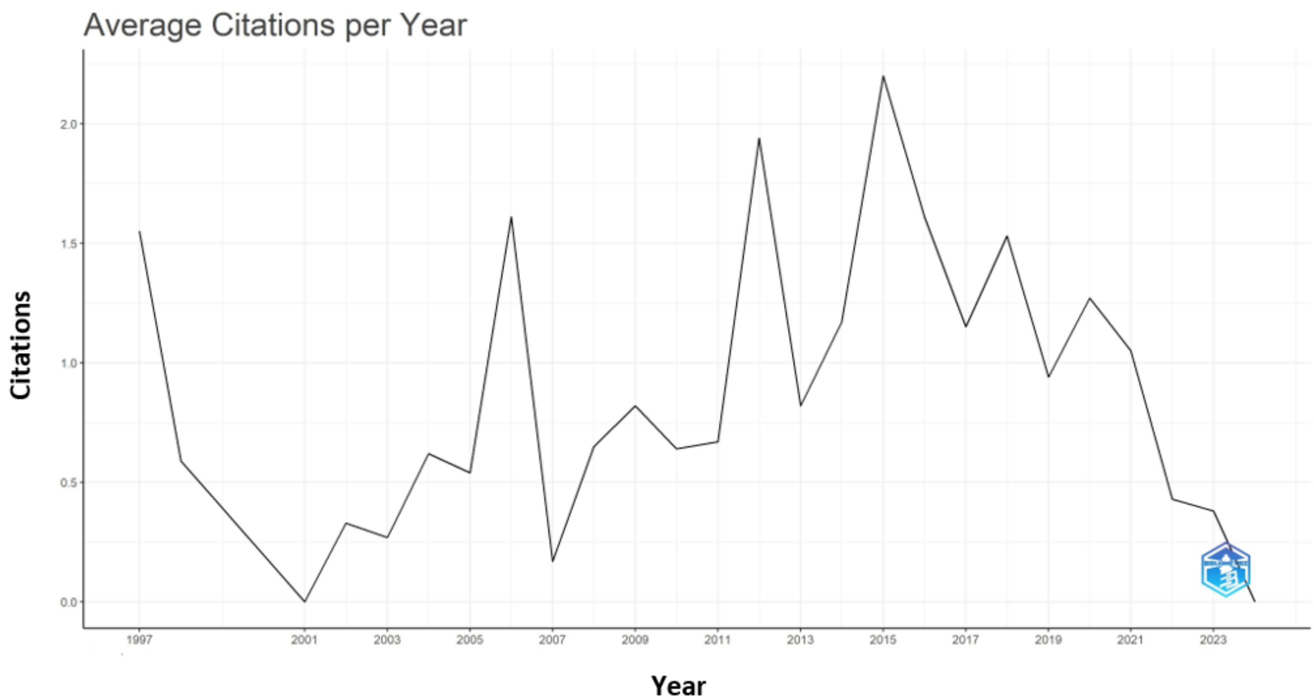

Fig. 6: The average citations per year in the field of intelligent software development.

7) Frequency Distribution of Scientific Productivity (Lotka's Law): This bibliometric analysis evaluates the Lotka's law coefficients for publications pertaining to intelligent software development. Lotka's law [48] delineates the relationship between authors and the volume of published articles. It characterizes the distribution of authors over time or within particular areas of informatics [40]. Figure 16 depicts the frequency distribution of scientific output according to Lotka's Law, while figure 17 demonstrates the significant adherence to Lotka's law in terms of publication count and author frequency within the topic of interest.

8) The Most Frequent Words: The terms "Agile" and "Software" emerged as the most frequently utilized terms by authors, with 368 and 264 mentions, respectively, followed by "development," which appeared 229 times. Figure 18 illustrates the prevalent words within the domain of intelligent software development. Additionally, figure 19 presents a word cloud [49] showcasing the most commonly employed keywords in research pertaining to the subject under investigation.

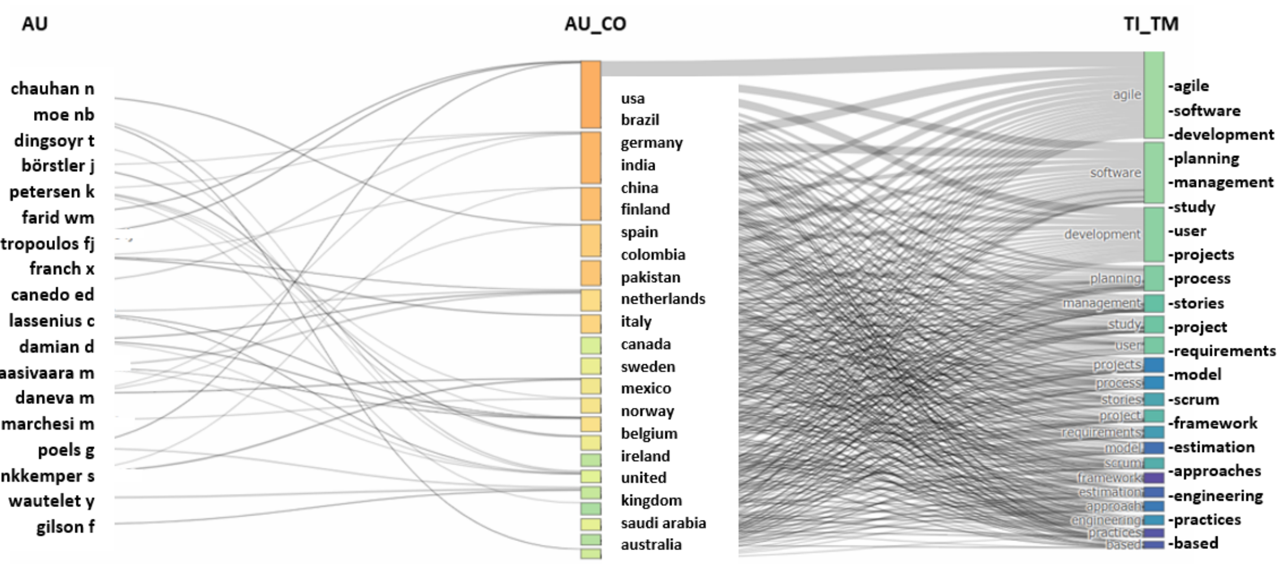

Fig. 7: The Three-Field plot of countries, authors and document title keywords.

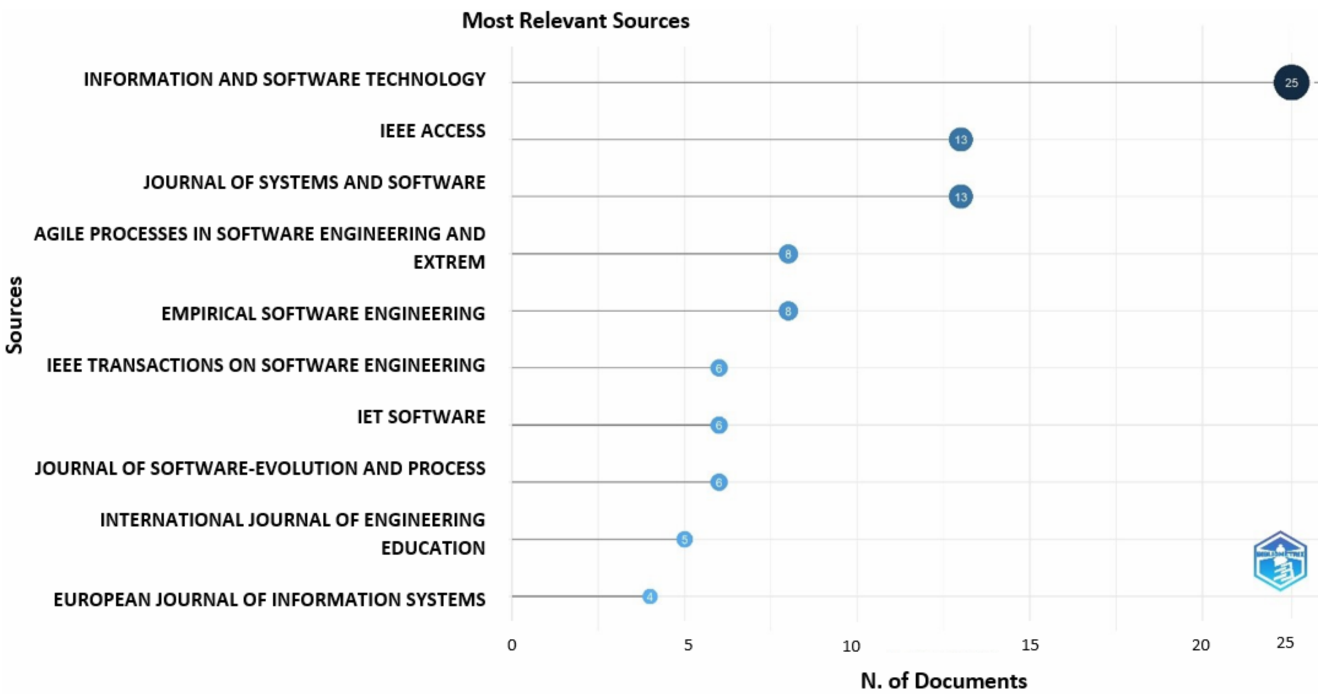

Fig. 8: Top 10 journals with the highest productivity.

The recurrence of these terms emphasizes the dominance of agile-related topics in the literature. Moreover, their co-occurrence with terms such as "scrum," "planning," and "user stories" suggests strong research interest in operational practices and project-level implementations of agile principles.

9) Collaboration World Map and Network: Illustrated in figures 20 and 21, the United States occupies the central position within the largest collaboration cluster [50], with Brazil, India and China in close proximity. Another notable cluster emerges, comprising Germany, Spain, and England. Additionally, a distinct cluster forms involving Canada, Finland, Norway, and France.

10) Keywords Co-Occurrence Network: Figure 22 depicts the keywords co-occurrence network, where each node represents a keyword. The size of each node corresponds to the frequency of the respective keyword's occurrence. Links between nodes indicate the co-occurrence of terms, with the thickness of the connections reflecting the frequency of such occurrences. Each color in the network signifies a thematic cluster. In particular, agile software development, agile, user stories, scrum, and software development emerge as the most prevalent keywords in various clusters.

11) Authors Co-Citation Network: Figure 23 presents a network illustrating authors' co-citations, which have been organized into four distinct clusters to showcase the interconnectedness among them. Notably, Schwaber, K garners the highest citation count within Cluster 1, characterized by authors specializing in agile methodologies and software development practices. Cohn, M holds the top position in Cluster 2, focusing on project management and requirements

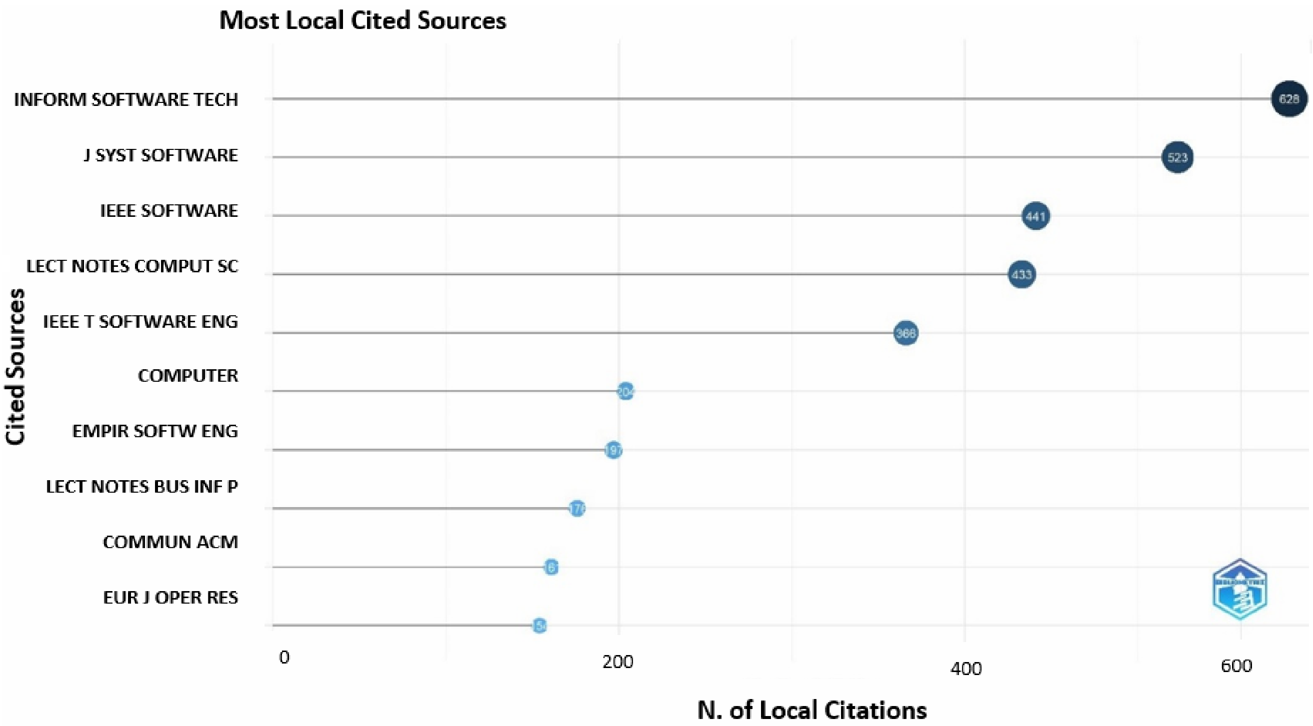

Fig. 9: Top ten highly cited sources.

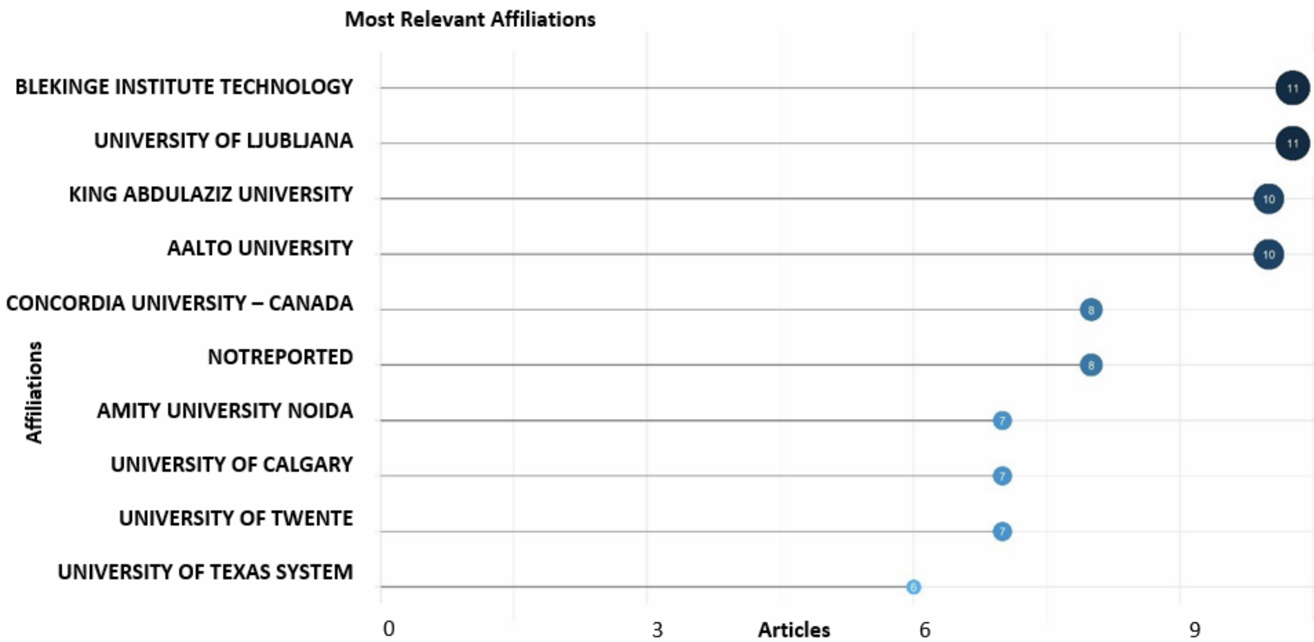

Fig. 10: Top ten most relevant affiliations.

engineering.

Similarly, Lucassen, G leads Cluster 3, emphasizing software quality and modeling, while Petersen, K emerges as the most cited author within Cluster 4, which concentrates on empirical software engineering studies. The interconnected nodes and edges in the network underscore the collaborative and interdisciplinary nature of the field, highlighting influential contributors and their thematic groupings within software development research.

12) Journals Co-Citations Network: Figure 24 illustrates a network of journal co-citations, showcasing 6 clusters that represent the interconnected citations among journals. The clusters highlight thematic groupings in software development research, with stronger links between journals indicating closely related research topics. Notably, "Information and Software Technology" stands out as the most cited journal, reflecting its central role in the field. The "IEEE Transactions on Software Engineering" journal and the "Lecture Notes in Computer Science" book series follow closely behind, emphasizing their significant contributions. This network demonstrates the collaborative nature of academic research, revealing the key sources shaping advancements in software development studies.

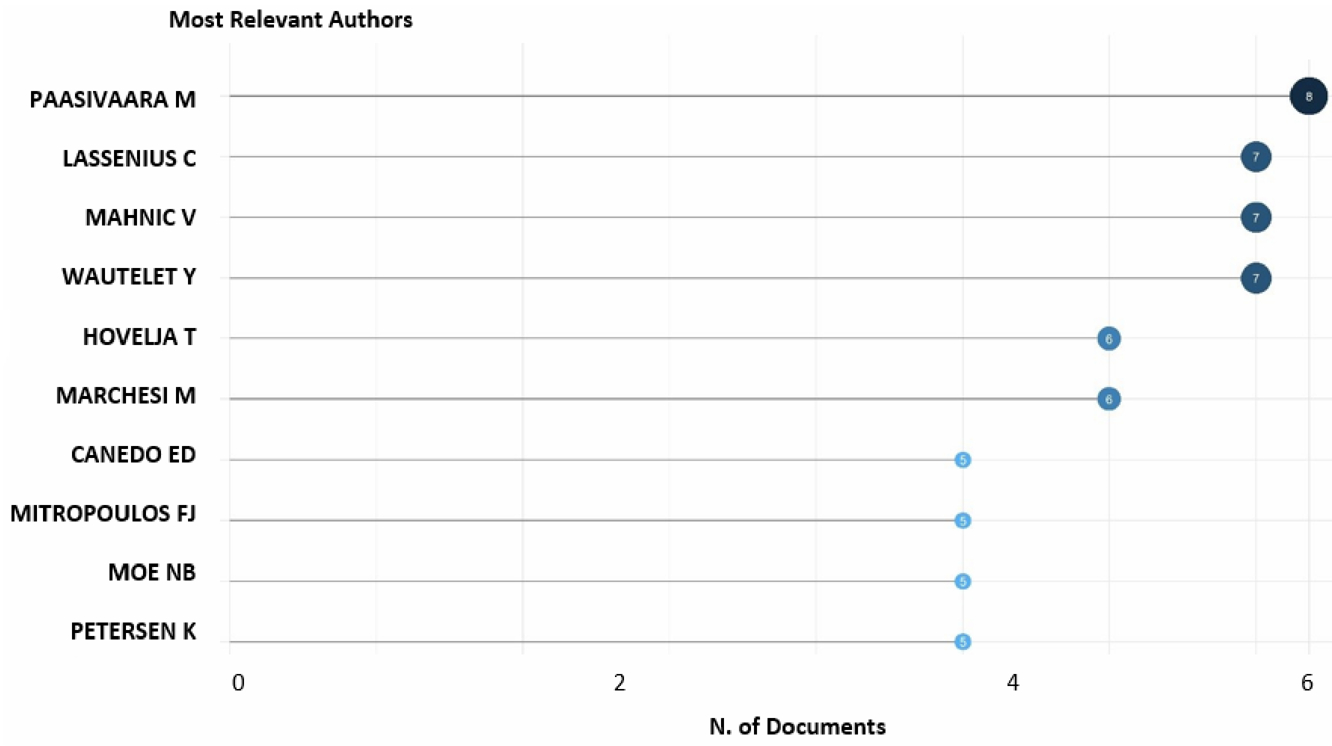

Fig. 11: Top ten most relevant authors.

Country	Articles	SCP	MCP	Freq	MCP_Ratio
USA	105	95	10	0.139	0.095
BRAZIL	52	44	8	0.069	0.154
INDIA	44	39	5	0.058	0.114
CHINA	37	27	10	0.049	0.270
GERMANY	32	29	3	0.042	0.094
CANADA	25	19	6	0.033	0.240
FINLAND	25	20	5	0.033	0.200
ITALY	24	18	6	0.032	0.250
SPAIN	24	13	11	0.032	0.458
SWEDEN	23	15	8	0.031	0.348

Fig. 12: Corresponding author's countries.

C. Network Analysis

1) Thematic Map: Thematic maps [51] represent clusters of keywords that can be visualized within a single circular arrangement, mapping them in a two-dimensional format based on their density and centrality. In figure 25, a thematic map is divided into quadrants according to their respective locations. The upper-right quadrant contains motor themes characterized by keywords with the highest degree of development and relevance. Basic themes reside in the lower-right quadrant, comprising keywords with high relevance but varying degrees of development. Emerging or declining topics are situated in the lower-left quadrant, consisting of keywords with moderate relevance and development. Niche themes occupy the upper-left quadrant, encompassing keywords with high development but potentially lower relevance.

2) Multiple Correspondence Analysis : As outlined in section IV, MCA serves as a tool for both graphical and mathematical analysis [52] of multivariate categorical data. By scrutinizing the interrelationships among various categorical data points, it aims to unveil latent variables or factors. Interpretation of results relies on the relative positioning and distribution of data points along the dimensions; closer proximity of terms in figure 26 indicates a higher degree of similarity in their distribution.

Figures 26 and 27 display the topic dendrogram and conceptual structure map, respectively, generated from the Keywords Plus of each paper. The y-axis denotes the height, indicating the distance between the words. Each cluster of words signifies a coherent topic.

3) Correspondence Analysis: In section IV, we elucidated the definition and purpose of correspondence analysis. This technique serves as a visual tool to explore the relationships among variables within a contingency table. It provides a means to condense and depict datasets using two-dimensional graphs. As illustrated in figure 28, the aim is to generate a comprehensive data visualization suitable for interpretation.

Figures 28 and 29 present the topic dendrogram and the conceptual structure map derived from the titles of

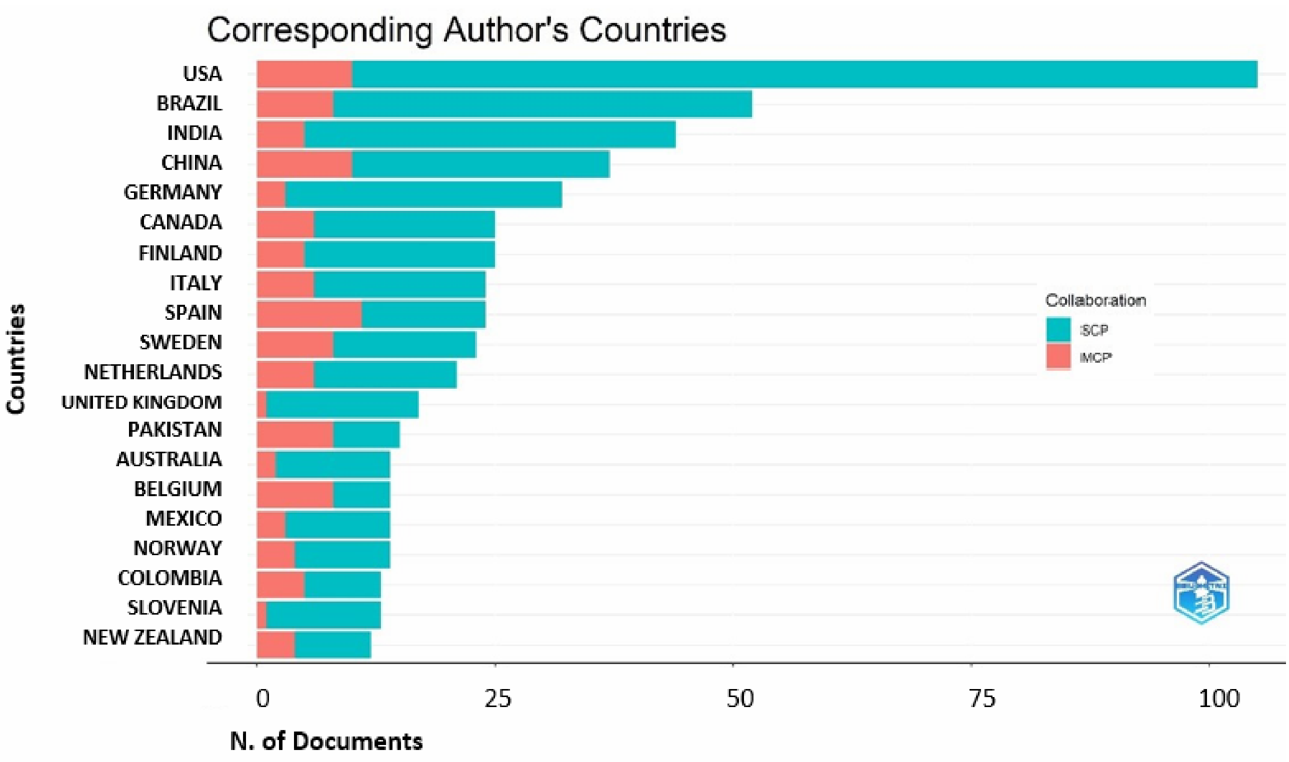

Fig. 13: The most relevant countries by corresponding authors.

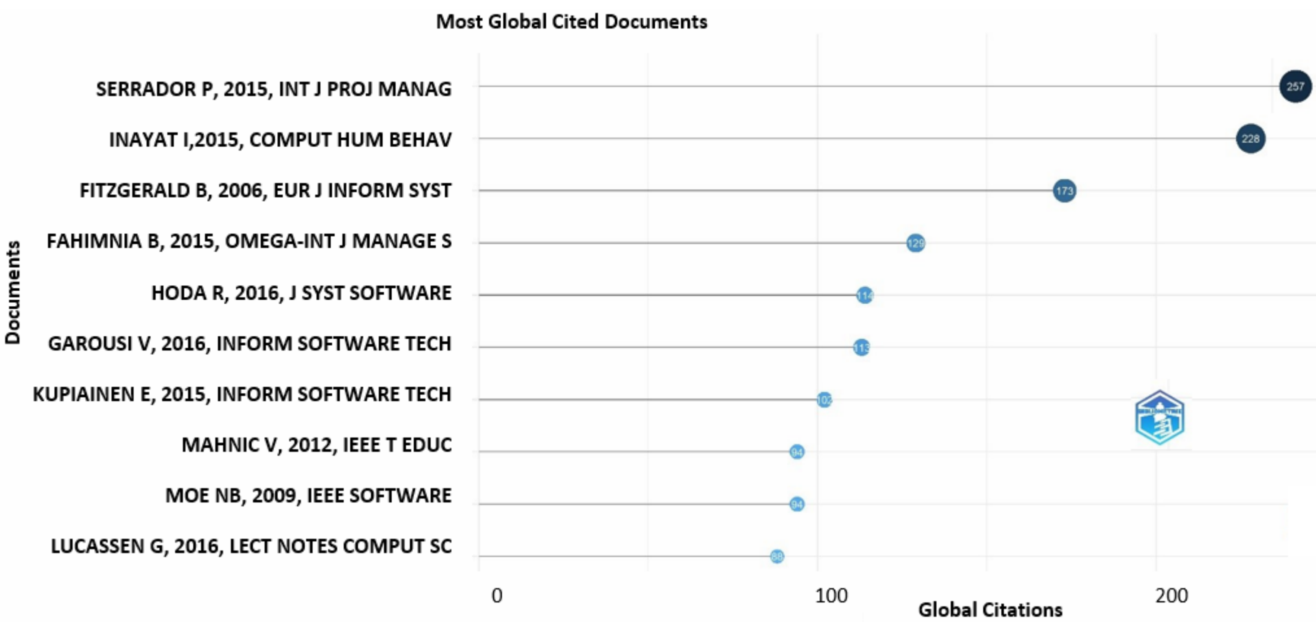

Fig. 14: Most globally cited documents.

individual papers. The y-axis depicts the height, representing the distance between words, with each grouping of words indicating a coherent topic.

4) Multidimensional Scaling: Figure 30 showcases the application of Multidimensional Scaling (MDS), discussed in section IV as a method for multivariate data analysis. Its purpose is to visually represent sample similarity and dissimilarity through points plotted on two-dimensional graphs. The MDS algorithm operates by taking input data from the dissimilarity matrix, which delineates distances between pairs of objects.

Additionally, in figure 30, the topic dendrogram was created using the author's keywords from each paper. The hierarchical clustering evident in the dendrogram effectively groups related topics, such as "sprint planning," "effort estimation," and "agile development," providing insight into thematic connections. These clusters highlight key research areas and relationships between them, offering a comprehensive understanding of the structural composition of the field, as driven by keyword associations. This combined approach enriches data interpretation and facilitates domain-specific exploration.

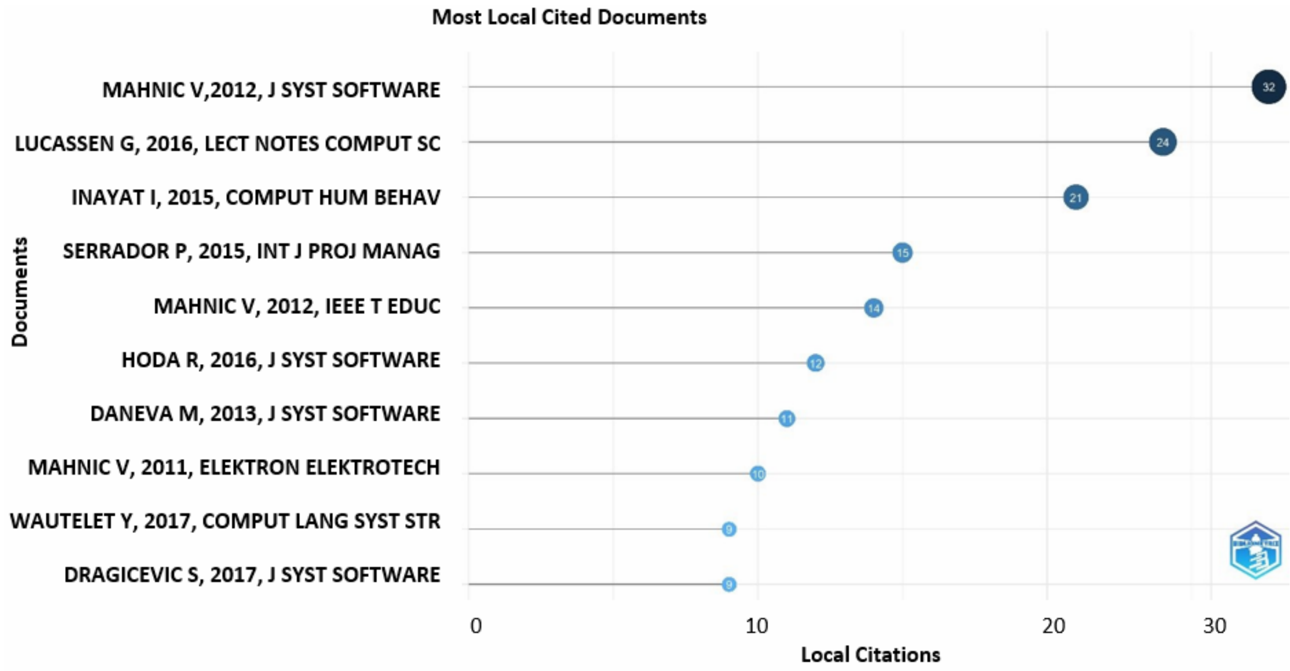

Fig. 15: Most Locally Cited Documents.

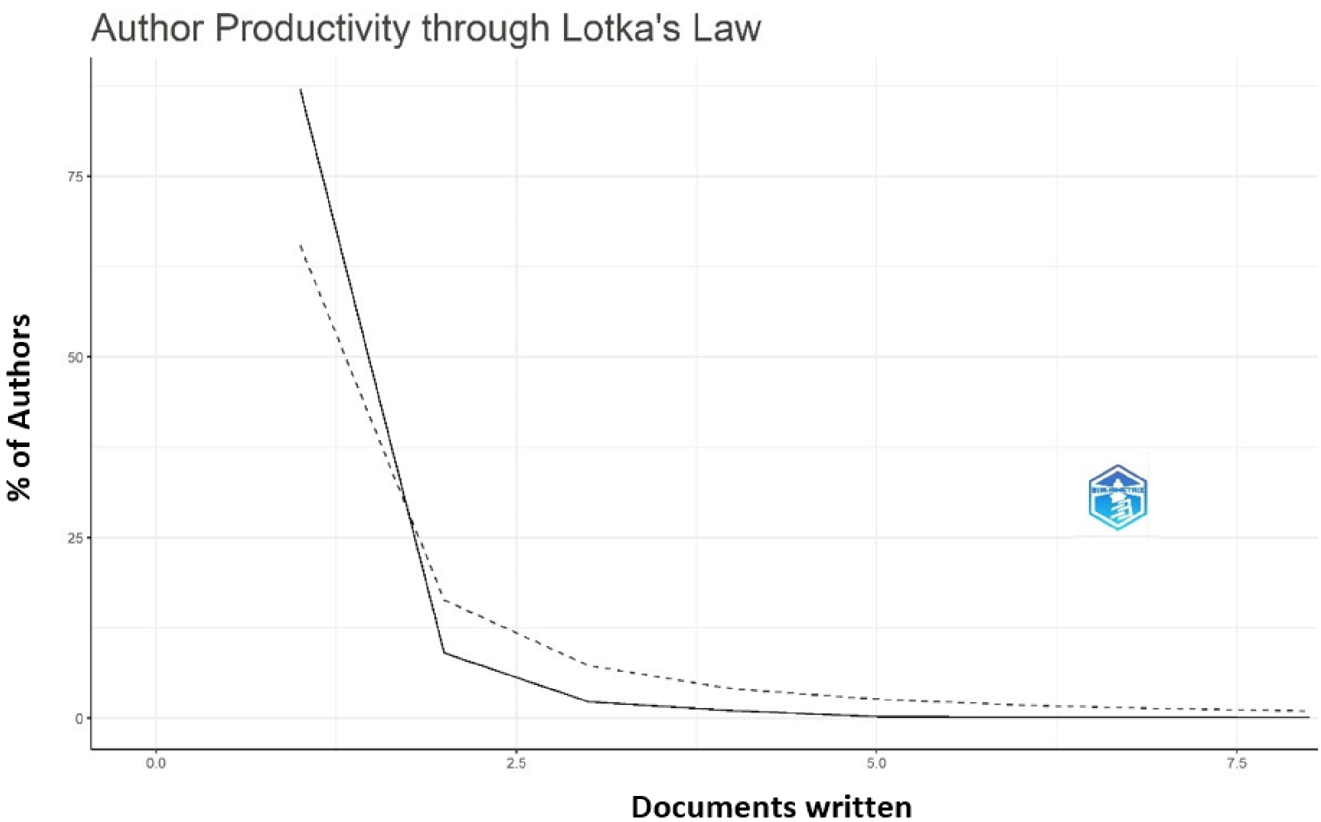

Fig. 16: Frequency Distribution of Scientific Productivity (Lotka's Law).

VI. Discussion

The findings from this bibliometric analysis and content examination have given rise to numerous interpretations and consequences, igniting extensive discussions. This investigation encompassed 754 papers on intelligent software development authored by 2062 individuals between 1997 and 2024, with an average citation rate of 9.40. The data reveals a prevalent trend of co-authorship, with only 3.93% of the papers being single-authored, underscoring the substantial collaborative nature within this domain.

The use of three-field plots, incorporating essential metadata fields [53], [54], provides insightful connections between domains. These plots facilitate the linking of author's contributions to particular keywords and the countries engaged in research. For example, the authors Mitropoulos FJ, Gilson F, and Chauhan N, representing the USA, Belgium,

Documents written	N. of Authors	Proportion of Authors
1	1796	0.871
2	186	0.090
3	47	0.023
4	22	0.011
5	5	0.002
6	2	0.001
7	3	0.001
8	1	0.000

Fig. 17: Frequency distribution of scientific productivity according to Lotka's law.

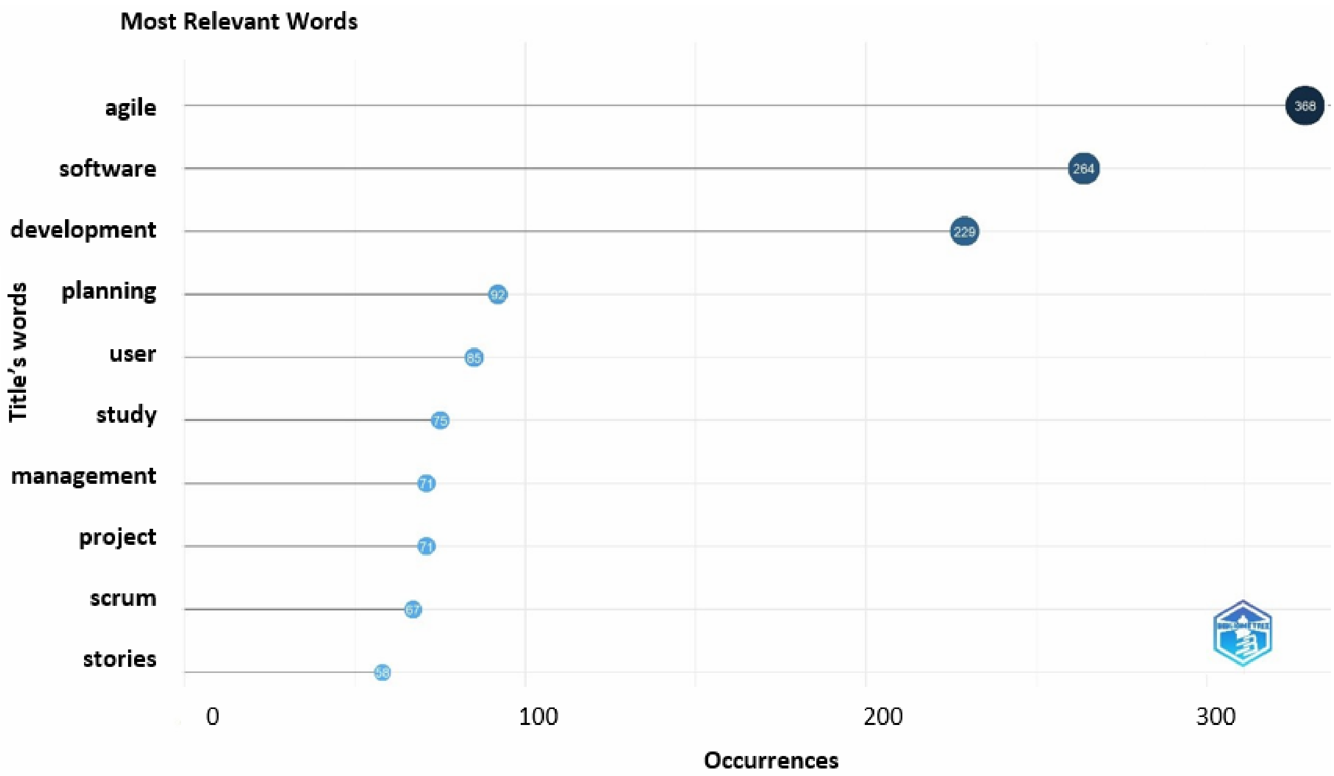

Fig. 18: The most relevant words used in intelligent software development research.

Fig. 19: Word cloud of the most frequently used keywords in software development research.

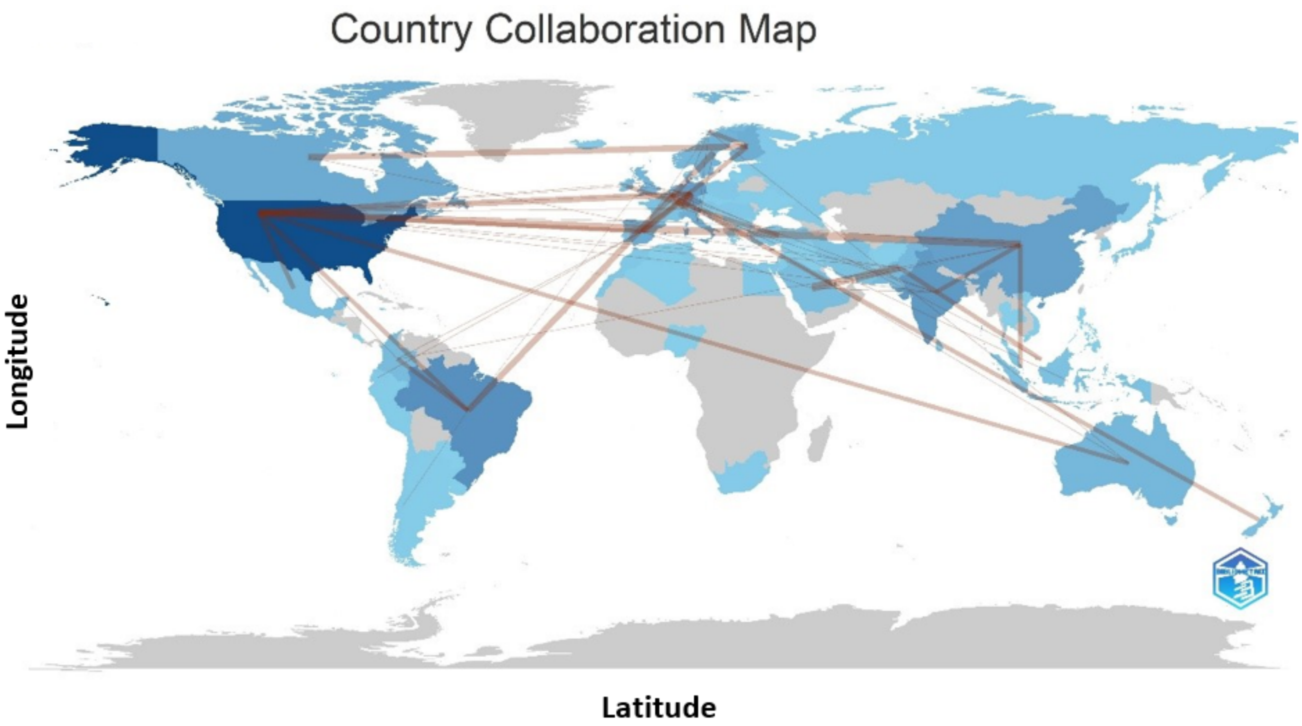

Fig. 20: Country collaboration world map.

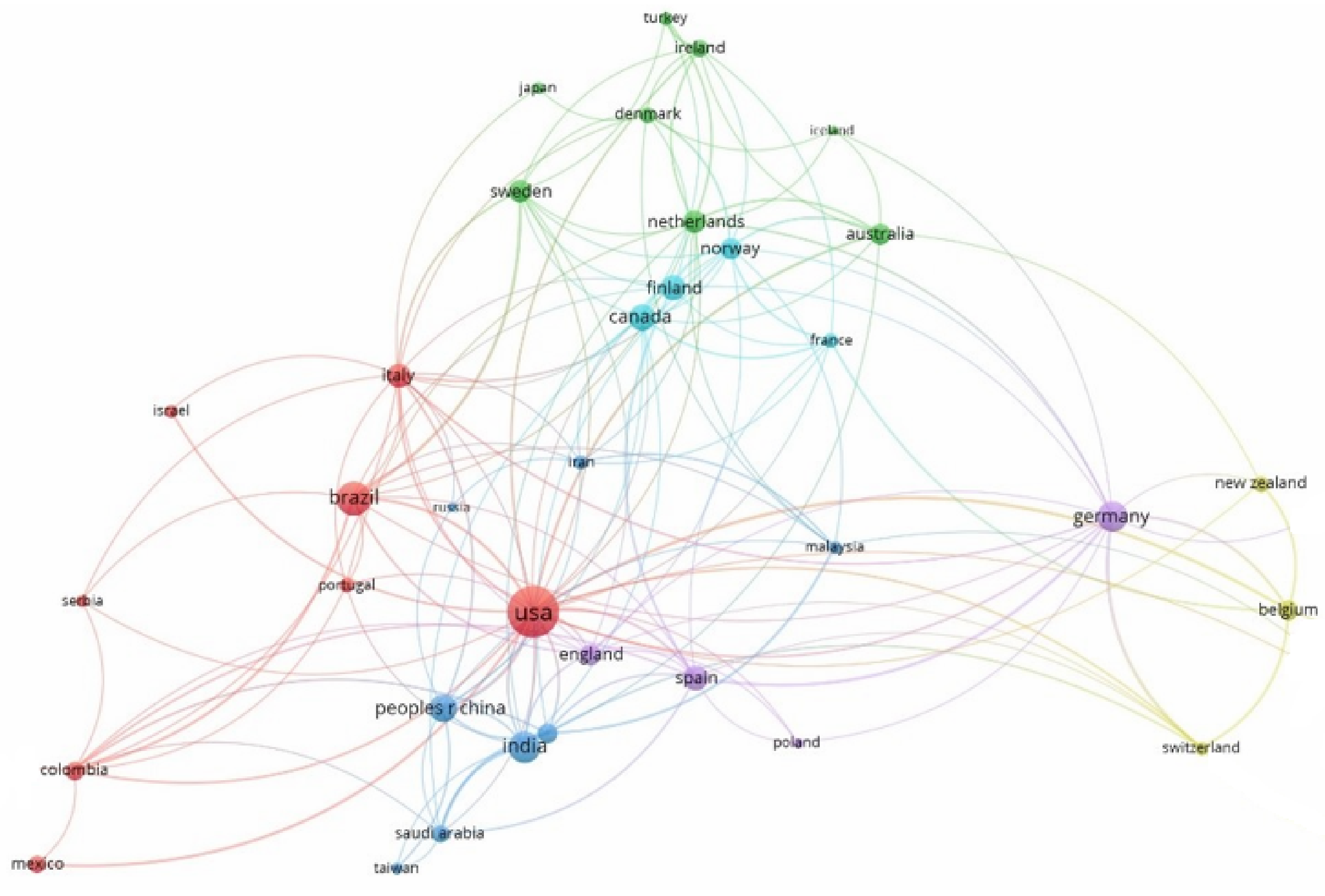

Fig. 21: Country collaboration world map via VOS Viewer.

and India, respectively, exerted a significant influence on agile software development studies [55]–[57]. Additionally, our findings indicate a strong correlation between research topics explored in the USA, Brazil, and Germany.

The findings revealed the presence of 7 keyword clusters, each containing 12 or more terms. Cluster 1 encompasses 26 words related to agile software development, agile methodologies, and agile project management [58]–[60]. Cluster 2

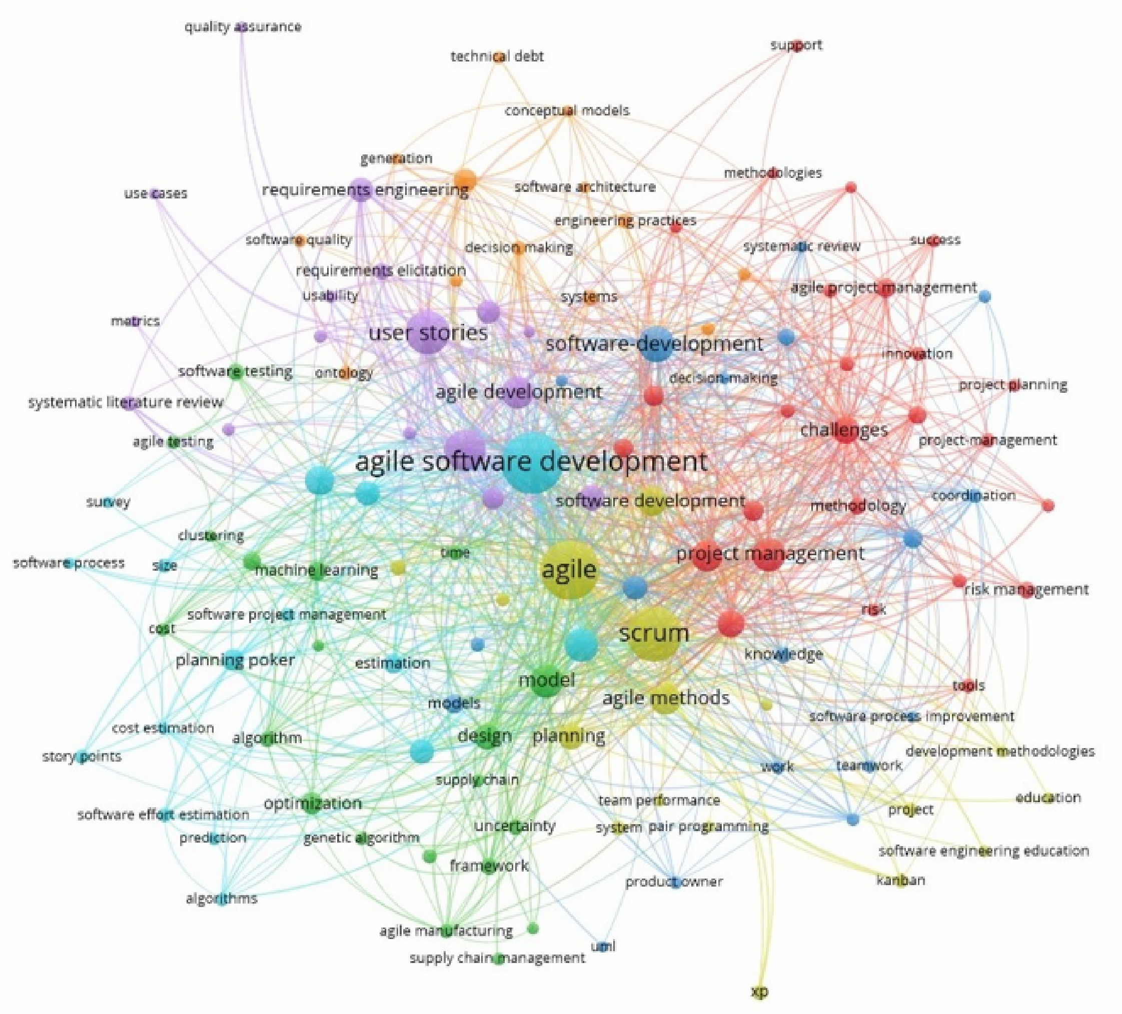

Fig. 22: Keywords co-occurrence network.

consists of 20 keywords related to artificial intelligence [61]–[64], machine learning [65]–[67], and various software development practices. Cluster 3 comprises 18 keywords primarily focusing on agile practices and software development. Cluster 4 encompasses 17 keywords closely associated with agile methods. Cluster 5 contains 17 keywords emphasizing software engineering principles and tools. Cluster 6 includes 16 keywords related to algorithms and user stories, while cluster 7 comprises 13 keywords centered around software quality and natural language processing. These findings underscore the widespread adoption of agile methodologies aimed at enhancing development quality in software engineering [68], [69].

Thematic maps offer a visual representation of the structural and dynamic elements within a research domain by employing knowledge frameworks. They aid in delineating conceptual structures that delineate the primary themes, subjects, and intellectual frameworks shaping an author's impact on the scientific community. These conceptual frameworks serve to present a comprehensive overview of significant trends and discoveries in software development research. Furthermore, they facilitate the examination of the evolution of ideas or circumstances over time. This method equips scholars with curated lists of prominent papers within each thematic cluster, enabling focused study on specific themes. Through assessing centrality and density, scientific maps provide insights into the significance of topics and allow for predictions regarding their potential future growth.

The findings of the bibliometric analysis reveal that a select cohort of authors contributes significantly to the most renowned works. Given the widespread availability of open-access papers, contributions are swiftly disseminated, fostering the emergence of a multitude of writers as the topic evolves. Notably, there is a discernible trend towards increased citations, exemplified by the most cited paper accruing 628 citations, indicating its current importance. The USA, Brazil, and Germany occupy the top three positions for scientific output in this field, a predictable outcome given their consistent dominance in global scientific productivity across all domains [70]. These findings underscore the interdisciplinary nature of the study, as even the most prolific researchers employ diverse approaches and expertise. To effectively disseminate knowledge to all stakeholders, journals must be both efficient and comprehensive. Our analysis identifies "Information and Software Technology," "IEEE Access," and "Journal of Systems and Software" as the top three sources with the highest citation rates on the subject, highlighting their pivotal role in facilitating knowledge dissemination.

This study exclusively examined articles related to intel-

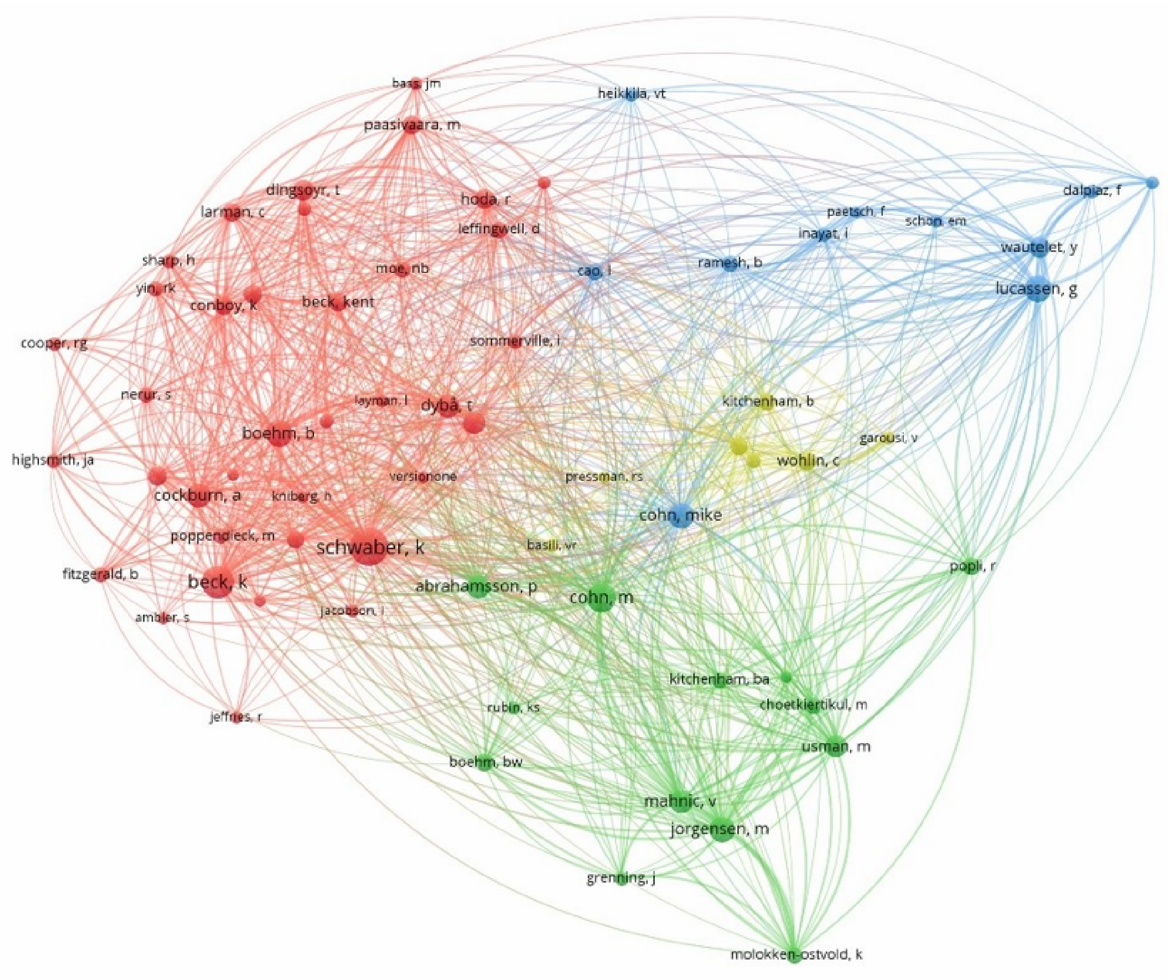

Fig. 23: Authors co-citation network.

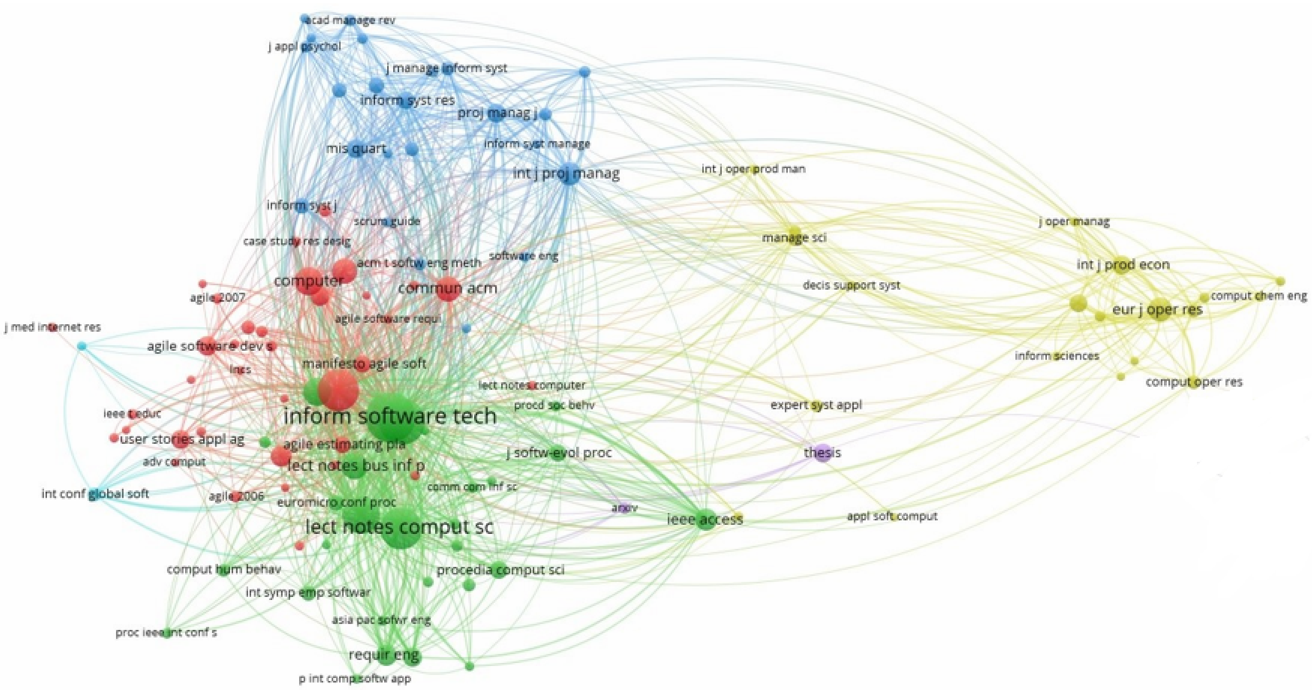

Fig. 24: Journals co-citation network.

ligent software development that were included in the Web of Science core collection database. While the comparison of datasets across multiple databases was not within the scope of this research, exploring additional databases could

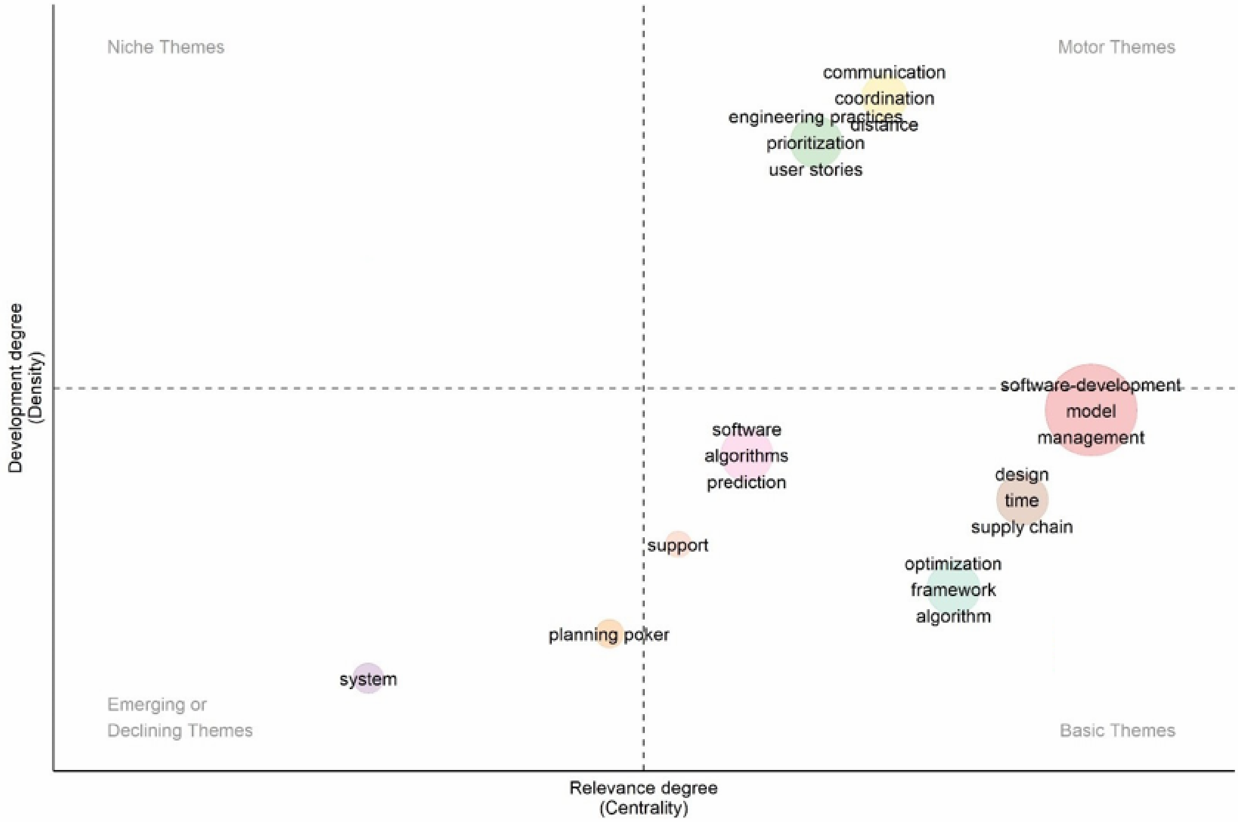

Fig. 25: Thematic map.

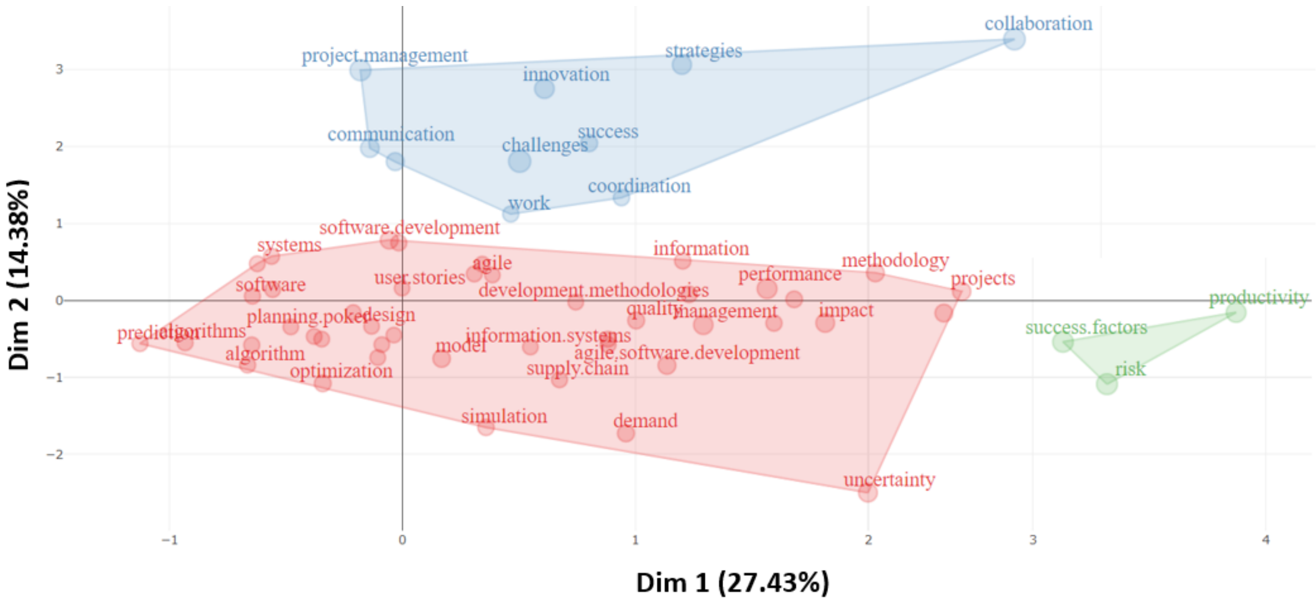

Fig. 26: Conceptual structure map using multiple correspondence analysis.

yield alternative sets of items, potentially leading to differing outcomes in the analysis [71], [72].

In undertaking this study, the authors diligently endeavored to comprehensively search for all pertinent material concerning the topic. However, the study is subject to several limitations, including: a search period confined to 1997–2024; reliance on the WoS database, which may not encompass all indexed journals and could overlook relevant publications; constraints inherent in the search methodology, potentially resulting in false positives or negatives; and a concentration on english language papers, which may introduce a bias towards english-speaking nations.

Finally, this study highlights the critical role of interdisciplinary collaboration and the integration of advanced methodologies in advancing research on intelligent software development. Future investigations could benefit from a broader scope, incorporating multilingual and cross-database analyses to yield a more inclusive and representative understanding of the global research landscape [73]–[75].

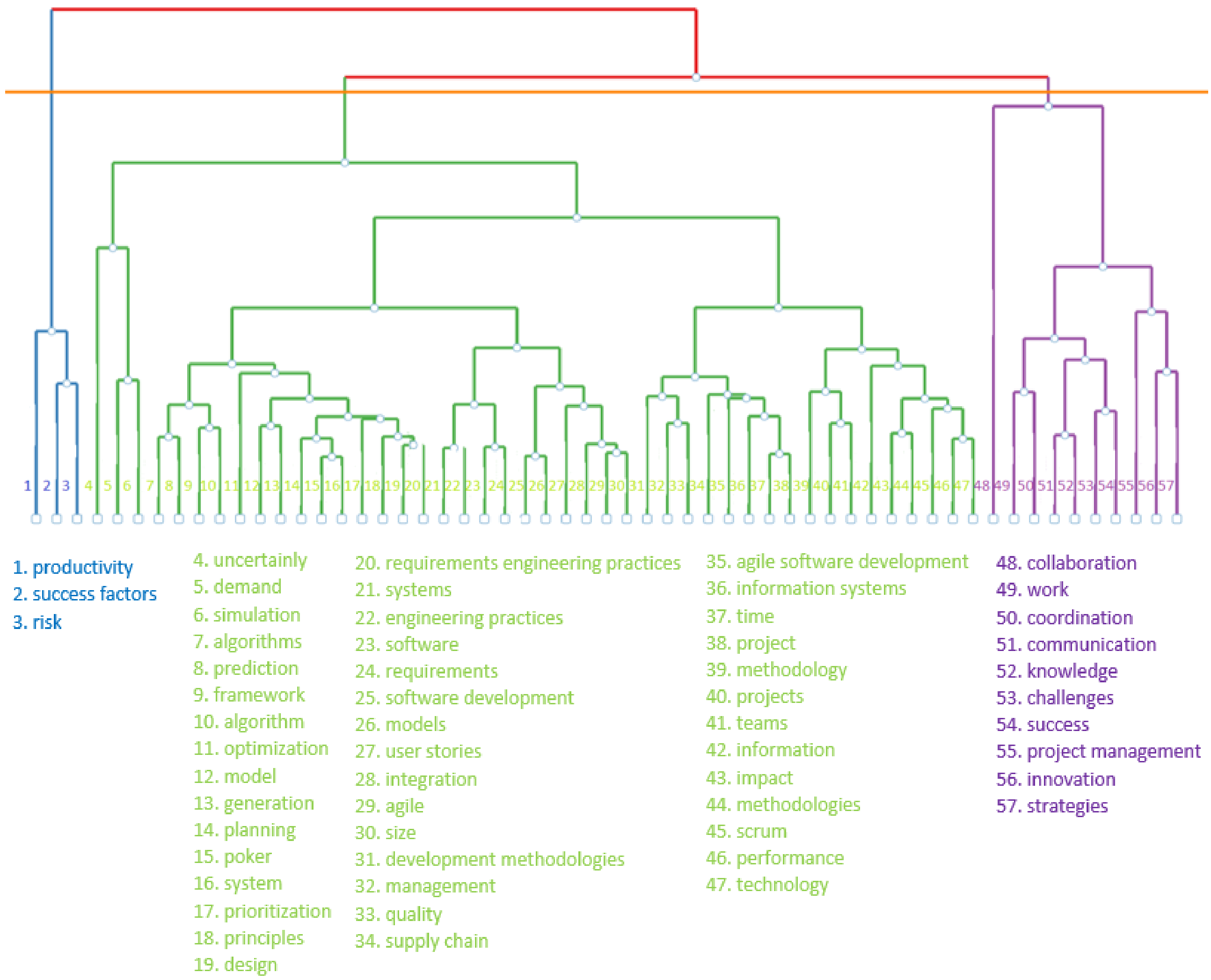

Fig. 27: Topic Dendrogram using multiple correspondence analysis.

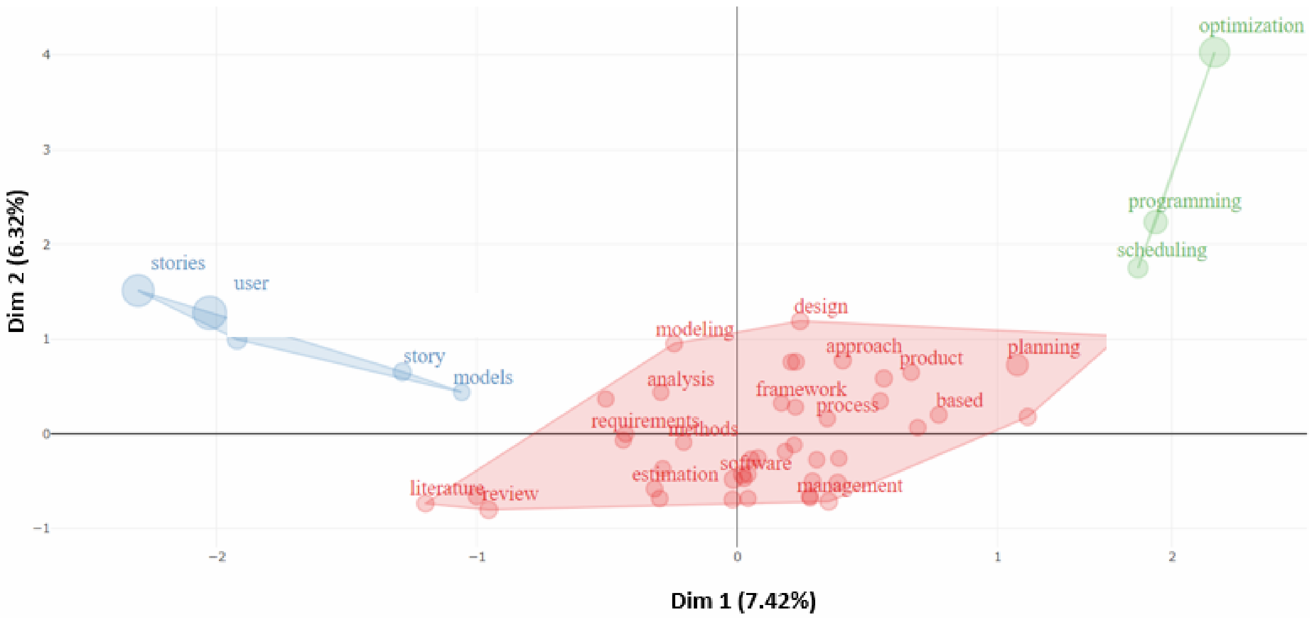

Fig. 28: Conceptual structure map using correspondence analysis.

VII. Conclusion

This bibliometric analysis paper examines 754 publications spanning from 1997 to 2024 across 11 research questions. Using data from the Web of Science database, it conducts a comprehensive comparison and evaluation of global

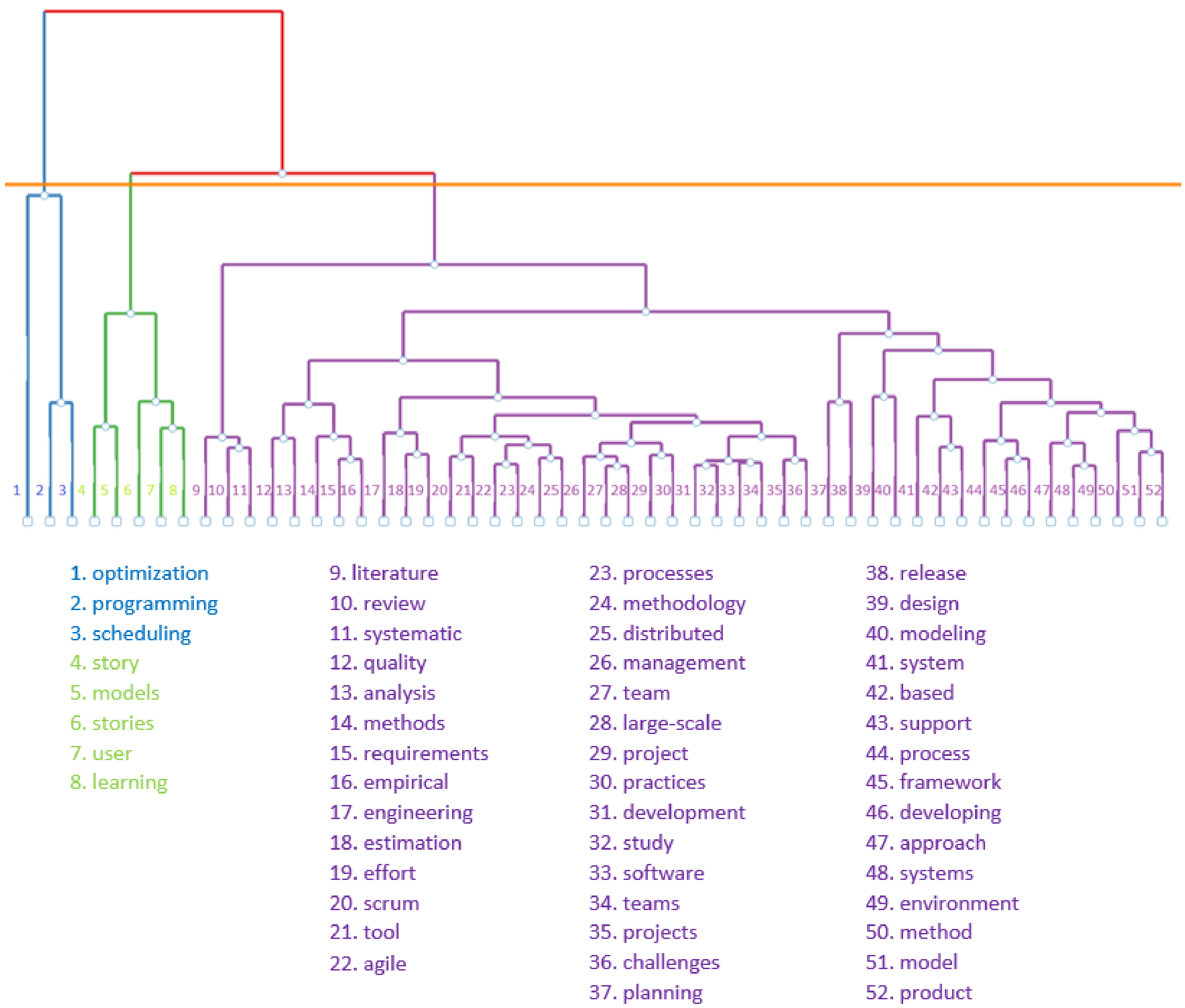

Fig. 29: Topic Dendrogram using correspondence analysis.

research output concerning intelligent software development. Additionally, the paper identifies the most influential researchers worldwide, mapping their geographical distribution and publication patterns. The analysis employs VOSviewer and the Biblioshiny program from the Bibliometrix package for R to analyze the data and generate insightful visualizations. The scientific publication trends reveal an average citation rate of 9.40, with the United States, Brazil and Germany emerging as the top three countries in scientific production within this field. Notably, collaboration levels are high, with only 3.93% of papers being single-authored. "Information and Software Technology", "IEEE Access" and "Journal of Systems and Software" emerge as the top three sources with the highest citations in the subject area.

Our findings are expected to offer insights into potential future research directions and perspectives within the rapidly advancing field of software engineering. By providing a comprehensive summary of trends associated with research in intelligent software development, our study aims to inform ongoing and forthcoming investigations. Numerous opportunities for substantial future work are anticipated to emerge from our analysis.

In the future of bibliometric analysis within agile software engineering, researchers will delve deeper into the nuanced dynamics of agile methodologies, examining their adaptation and evolution across diverse contexts. By harnessing advanced bibliometric techniques, scholars will map out the interdisciplinary connections between agile principles and related fields, such as project management and software quality assurance. Additionally, there will be a concerted effort to quantify the influence of agile practices on team collaboration, software development efficiency, and overall project success rates. This comprehensive analysis will not only inform practitioners about emerging trends but also guide future research directions, fostering continuous improvement and innovation in agile software engineering.

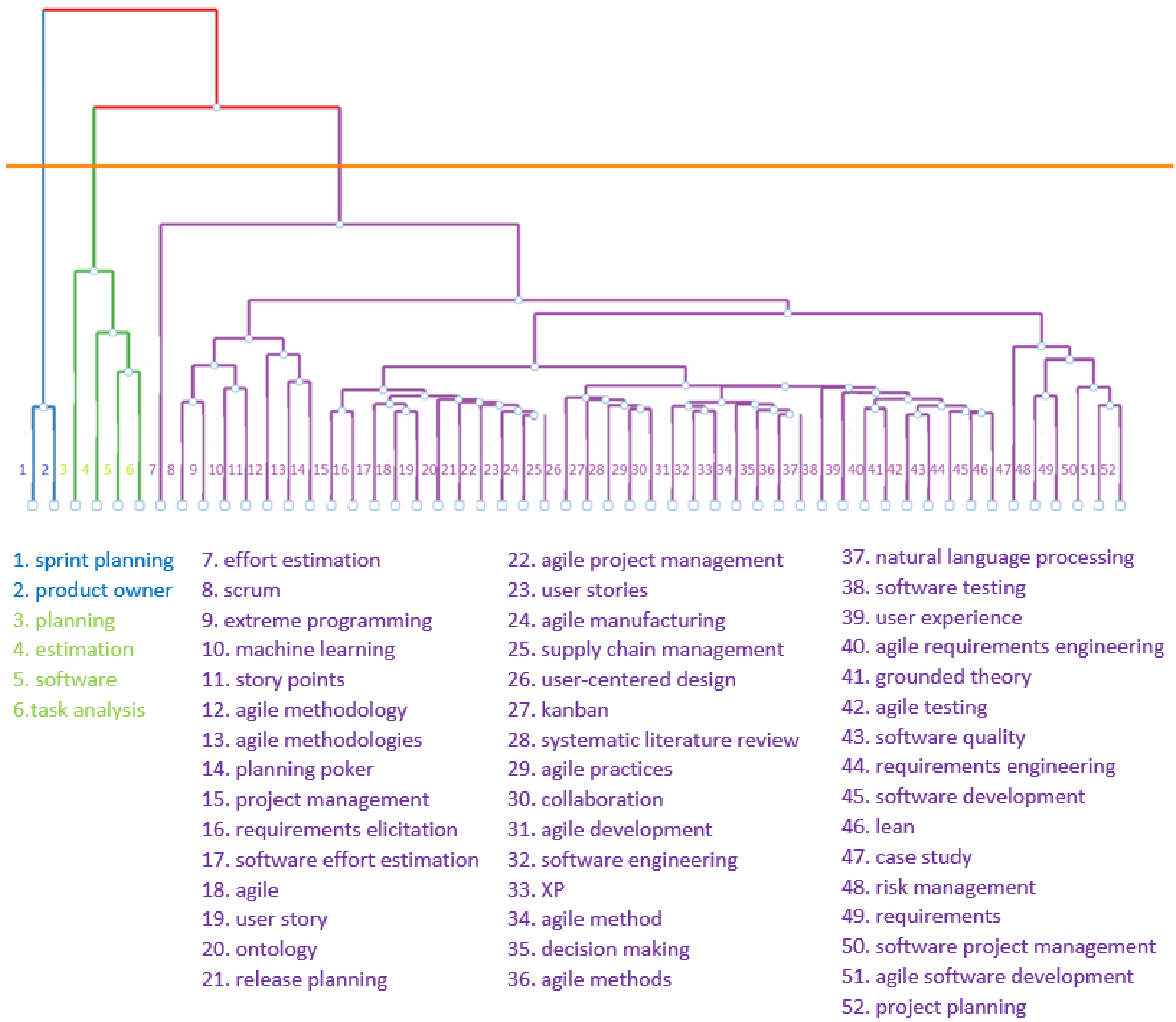

Fig. 30: Topic Dendrogram using multidimensional scaling.

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