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How is Software Engineering Linked to Business? A Scopus-Based Bibliometric and Visualization

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Abstract

Software engineering has significantly impacted various fields, including business, yet there had been no comprehensive bibliometric analysis of its interaction with business until this study. This research filled the gap by examining key contributors, affiliations, countries, and leading journals using a bibliometric analysis of 100 Scopus-indexed documents. The study revealed a peak in publications in 2008 with 11 documents, highlighting Gruhn, V. from Universität Leipzig, Germany, as the most prolific author. Both Germany and the United States were prominent, contributing 21 documents each. "Lecture Notes in Computer Science," along with its subseries, emerged as the most cited reference. The keyword analysis identified four main clusters focusing on the integration of IT, practical business applications, the role of education, and project management. The study recommends expanding research into Agile methodologies, UX Design, and technologies like AI, Cloud Computing, and IoT, providing insights into integrating software engineering into business strategies for future challenges.

A. Introduction

The role of software engineering in business advancement has been extensively studied. Schmitz, Feldmann, and Moldt [1] analyzed a software engineering course using process mining and business intelligence for deeper curriculum integration insights. Djan and de Vries [2] employed the Story-Card method to reengineer business processes, highlighting its adaptability. Nguyen-Duc et al. [3] discussed the essentials of software startups, emphasizing the early integration of technical and business aspects.

Washizaki et al. [4] [5] underscored the value-driven approach in software engineering, urging further exploration of its societal impacts. Fedotov and colleagues [6] improved software engineering algorithms for business, showcasing enhanced operational efficiency. Pashchenko [7] covered digitalization in software engineering, pivotal for understanding digital transformation.

Madakam and Revulagadda [8] emphasized the need for software engineering analytics post-COVID-19, considering global strategy shifts. Kontsevoi, Kizyan, and Dubovik [9] highlighted how predictive software engineering could foster personalized business solutions. Pal [10] used software engineering for data analytics in the apparel industry, demonstrating its sector-specific applications.

Despite extensive literature, no Scopus-indexed paper specifically analyzed the relationship between software engineering and business, leading to a knowledge gap about the most productive authors, affiliations, and countries, as well as impactful journals and under-researched topics. This study aims to address these gaps by identifying key contributors and suggesting future research directions in software engineering and business.

B. Research Method

This study utilized a literature review and bibliometric analysis methodology, examining 100 Scopus-indexed documents as of December 2, 2024, gathered through keyword search *(TITLE (software AND engineering) AND TITLE (business))*. The Scopus database was selected because it is an index that has compiled high-quality documents from various leading publishers in the field of computer science, such as IEEE, ACM, and others. In this analysis, no exclusion of documents was carried out; each entry that matched the search criteria was included in the dataset for further analysis. VOSviewer software was used for data visualization to enhance understanding of the data's distribution and relationships.

The analysis was divided into three types:

1) Descriptive Analysis

This assessed the scientific productivity of the documents, tracking metrics such as publication frequency, top authors, affiliations, countries, journals, document types, and subject areas, aiming to map the scientific landscape of software engineering in business.

2) Citation Analysis

This evaluated the impact of publications based on citation frequency to identify highly cited documents and recognize significant contributions to the field.

3) Keywords Analysis

Using VOSviewer for network analysis of keyword co-occurrence, this part explored the interconnections within the field, contributing to the evolution of research in software engineering and business.

C. Result and Discussion

1) Descriptive Analysis

The following is a descriptive analysis of 100 documents on software engineering in business indexed by Scopus, comprising annual growth, top authors, top affiliations, top countries, top sources, document types, and subject areas.

a) Annual Growth

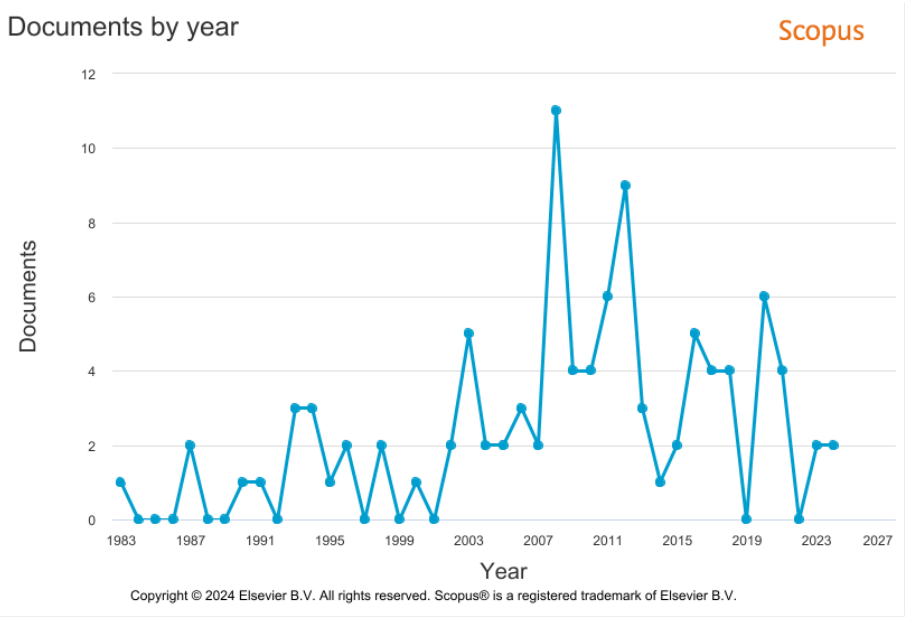

Figure 1. Annual growth of papers published related to the field.

Figure 1 shows the fluctuating trend of publications on business-related software engineering from 1983 to 2024. Starting with a single publication in 1983, there was significant variability over the next decade, peaking in 2008 with 11 papers. A notable decline followed until 2011 and 2012, which saw spikes of 6 and 9 publications, respectively. This pattern reflects changing interests and needs in the field. Post-2012, fluctuations became more moderate but maintained a positive trend.

b) Top Authors

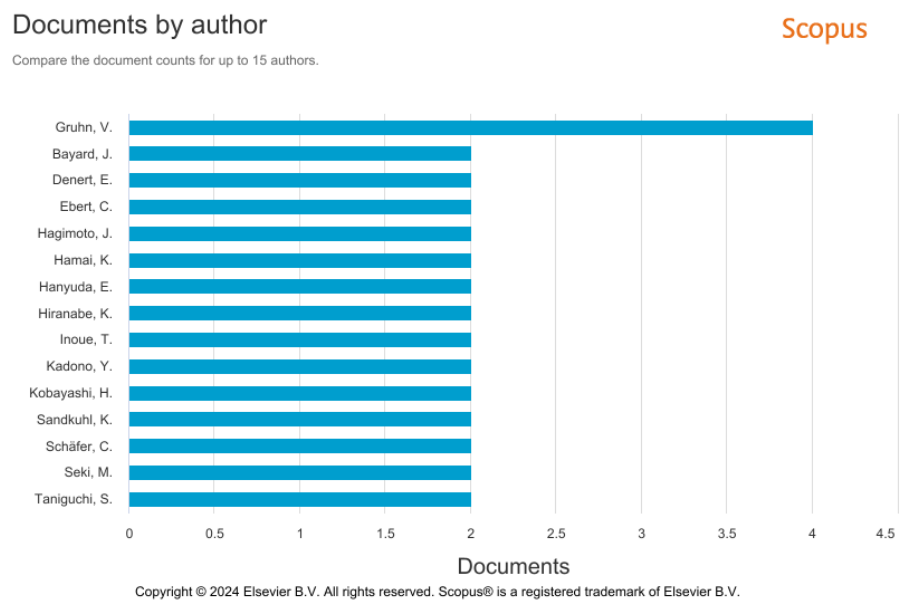

Figure 2. The most productive authors related to the field.

Figure 2 highlights the author's productivity in business-related software engineering. Gruhn, V. was the most productive with four indexed documents, followed by Bayard, J., Denert, E., and Ebert, C., each with two publications. This distribution underscores Gruhn, V.'s significant influence, likely due to a focused research agenda or active publication in this field. The continued contributions of these authors point to key centers of expertise in software engineering that intersect with business applications, offering vital insights into technological development and implementation.

c) Top Affiliations

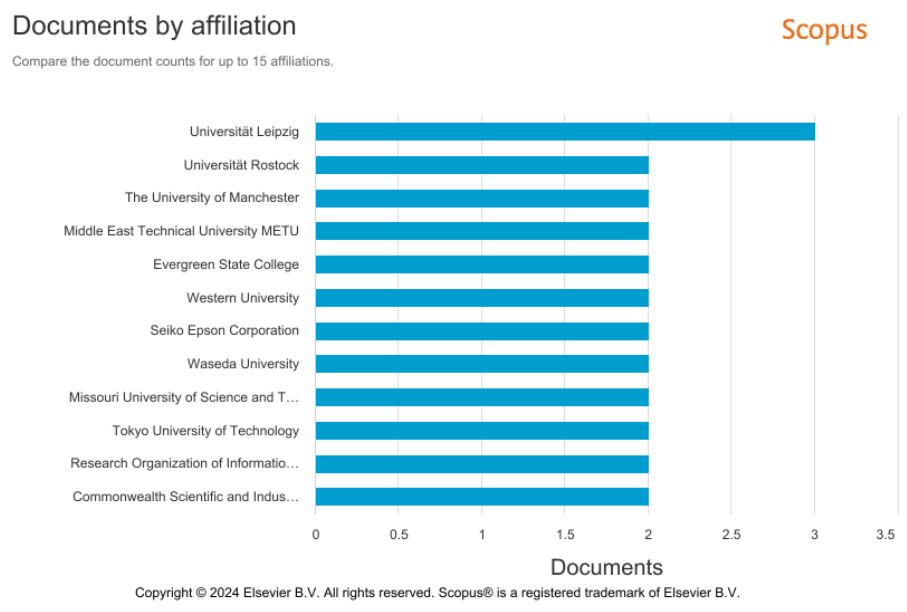

Figure 3. Top affiliations published related to the field.

Figure 3 from the Scopus database shows that Universität Leipzig led in publications linking software engineering to business with three documents. Other institutions like Universität Rostock, The University of Manchester, and Middle East Technical University (METU) each contributed two publications. The presence of industry players such as Seiko Epson Corporation and Waseda University underscores the vital collaboration between academia and industry in technology development. These results indicate significant contributions from global academic and corporate centers, advancing software engineering practices applicable in business contexts.

This list of institutions differs significantly from the results of the bibliometric study on software engineering from 2010-2017, where institutions from Germany and Japan had not yet dominated [11]. A bibliometric analysis from 2013–2020 still shows the dominance of the USA and the emerging presence of German affiliations, yet Japanese affiliations remain less visible [12].

d) Top Countries

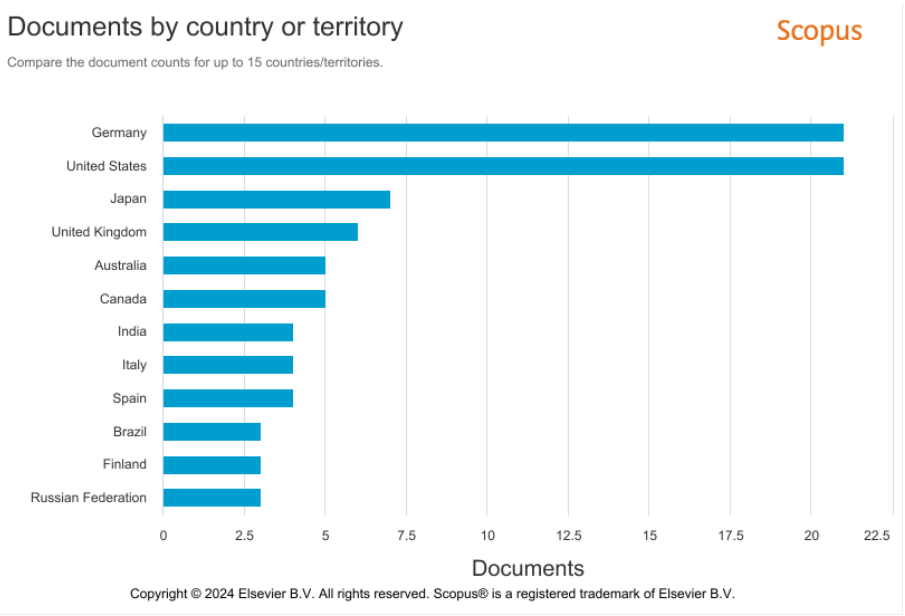

Figure 4. The most productive countries published related to the field.

Figure 4 from the Scopus database shows Germany and the United States leading in business-related software engineering publications, with each country producing 21 documents. Japan contributed 7 documents, while the United Kingdom and Australia added 6 and 5 respectively, indicating active regional research. Canada, India, Italy, and Spain each provided 4 publications; Brazil, Finland, and the Russian Federation each contributed 3, demonstrating the global reach and diversity of research in integrating software engineering with business. This reflects the widespread relevance of technology integration in global business strategies.

The bibliometric analysis from 2015 to 2019 on Machine Learning for Software Engineering indicated that the countries contributing the most papers were China, the USA, Canada, and Germany [13]. In the field of E-Learning Software Engineering Education, the UK replaced Canada among the most productive countries [14].

The USA's high number of publications was also attained through partnerships with other nations, such as Saudi Arabia, where the most international partnerships with US scholars were found in software engineering articles [15]. According to a 2007–2019 bibliometric study of software engineering, the United States and the People's Republic of China have the biggest research collaboration networks [16].

e) Top Sources

Table 1. The most productive sources in the field.

Source	**Documents**
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	7
Ceur Workshop Proceedings	3
Lecture Notes In Business Information Processing	3
Proceedings International Conference On Software Engineering	3

Table I shows significant contributions to business-oriented software engineering literature. "Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics" led with 7 documents, emphasizing its key role in merging computer science and artificial intelligence with business applications.

"CEUR Workshop Proceedings," "Lecture Notes in Business Information Processing," and "Proceedings of the International Conference on Software Engineering" each added 3 documents, highlighting the role of conferences and workshops in spreading the latest software engineering knowledge and practices. These publications demonstrate the diversity of platforms used for sharing research, reflecting the variety in themes and methods in this field.

f) Document Types

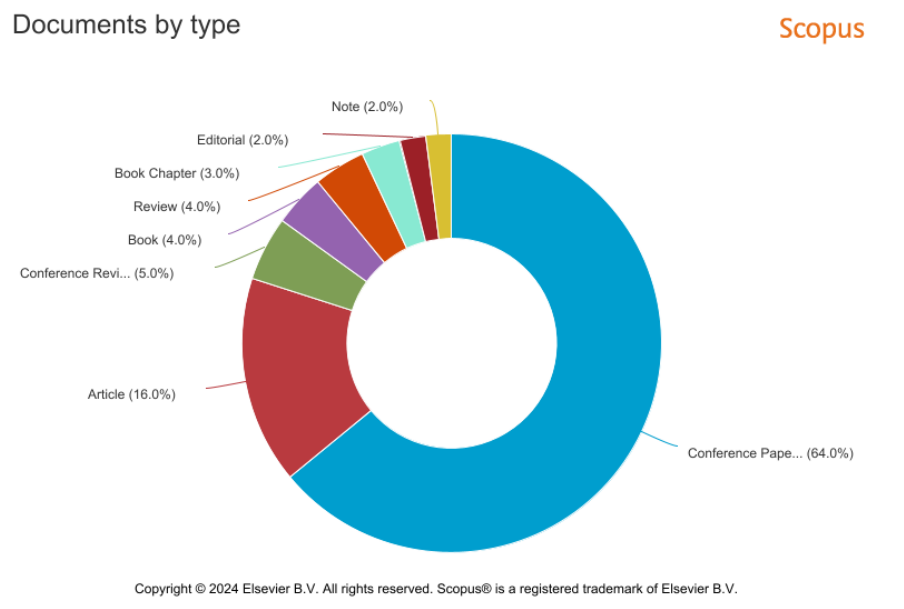

Figure 5. Document Types published related to the field.

Figure 5 showed that conference papers were the most published document type in software engineering and business, comprising 64% of total publications, indicating their key role as a primary forum for sharing innovations at the nexus of technology and business management. Journal articles, accounting for 16%, emphasized the significance of peer-reviewed research in this field.

Additionally, conference reviews, books, and book chapters made up 5%, 4%, and 3% of publications, respectively, while editorial and note-type publications each comprised 2%, reflecting targeted communications on recent developments. This distribution highlights the diverse formats used to disseminate research in business-related software engineering.

g) Subject Areas

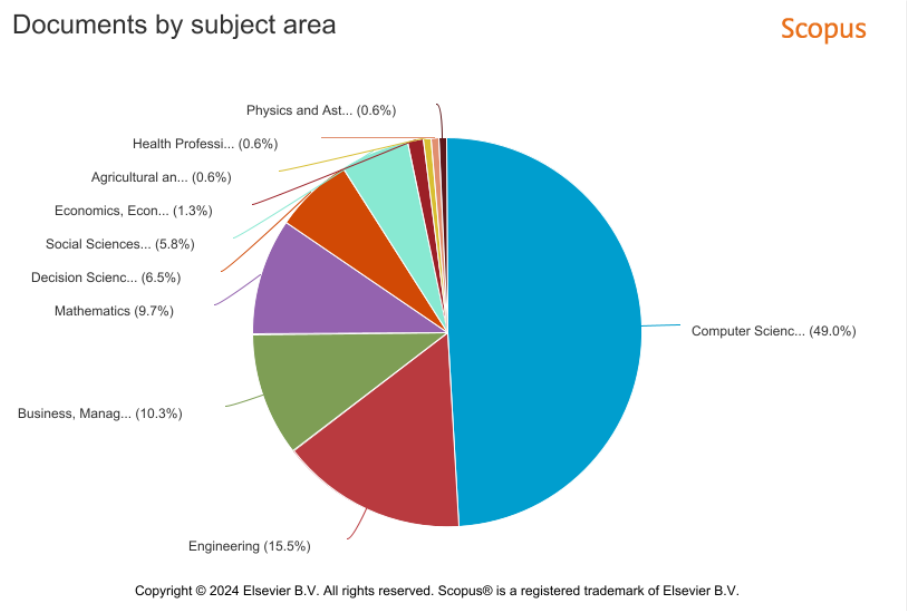

Figure 6. Top documents by subject areas.

Figure 6 revealed that Computer Science dominated the research combining software engineering and business, accounting for 49% of all documents, highlighting its critical role in driving business innovation and efficiency. The Engineering field followed with a 15.5% contribution, illustrating strong ties between engineering solutions and business applications. Business, Management, and Accounting made up 10.3%, emphasizing the management perspective in software technology implementation.

Mathematics and Decision Sciences also contributed 9.7% and 6.5%, respectively, emphasizing the importance of quantitative analysis and data-driven decision-making in business-related software development. Social Sciences accounted for another 5.8%, reflecting the societal and organizational impacts of information technology.

Additional contributions from fields like Economics, Agricultural Sciences, Health Professions, and Physics and Astronomy, though smaller, demonstrated the interdisciplinary nature of software engineering and business integration, showcasing the broad applicability of modern technology across various life and industry sectors.

2) Citation Analysis

Table 2. The Most Cited Papers in the Field.

No.	Article Details	Cited
1.	P. Bradley, J. Browne, S. Jackson, and H. Jagdev, 1995, *Business process re-engineering (BPR) - A study of the software tools currently available*, Computers in Industry [17]	49

2.	F. Soliman and M. A. Youssef, 1998, *The role of SAP software in business process re-engineering*, International Journal of Operations and Production Management [18]	39
3.	L. Lehtola, M. Kauppinen, J. Vähäniitty, and M. Komssi, 2009, *Linking business and requirements engineering: Is solution planning a missing activity in software product companies?*, Requirements Engineering [19]	28
4.	J. Hoffmann, I. Weber, and F. M. Kraft, 2012, *SAP speaks PDDL: Exploiting a software-engineering model for planning in business process management*, Journal of Artificial Intelligence Research [20]	24
5.	T. Menzies, O. Elrawas, J. Hihn, M. Feather, R. Madachy, and B. Boehm, 2007, *The business case for automated software engineering*, ASE'07 - 2007 ACM/IEEE International Conference on Automated Software Engineering [21]	22
6.	L. G. Williams and C. U. Smith, 2003, *Making the Business Case for Software Performance Engineering*, 29th International Computer Measurement Group Conference, CMG 2003 [22]	21
7.	A. Gonźlez, S. España, and O. Pastor, 2009, *Unity criteria for business process modelling : A theoretical argumentation for a software engineering recurrent problem*, Proceedings of the 2009 3rd International Conference on Research Challenges in Information Science, RCIS 2009 [23]	20
8.	E. R. Olsen, 2006, *Transitioning to software as a service: Realigning software engineering practices with the new business model*, 2006 IEEE International Conference on Service Operations and Logistics, and Informatics, SOLI 2006 [24]	20
9.	F. Ahmed and L. F. Capretz, 2011, *A business maturity model of software product line engineering*, Information Systems Frontiers [25]	17
10.	C. W. Krueger, D. Churchett, and R. Buhrdorf, 2008, *HomeAway's transition to software product line practice: Engineering and business results in 60 days*, Proceedings - 12th International Software Product Line Conference, SPLC 2008 [26]	14

Table II displayed the 10 most cited documents in the context of software engineering and business, revealing no single author or publication source dominated, as none appeared more than once. The year 2009 emerged as the most impactful, featuring two highly cited documents, suggesting that older, high-quality research continues to attract significant attention and citations due to its enduring relevance to current technology and markets.

3) Keywords Analysis

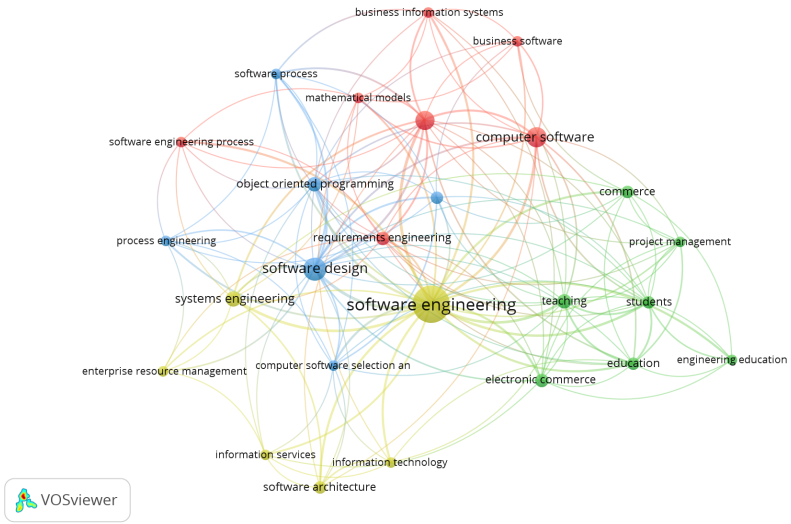

Figure 7. Visualization of most frequently occurring keywords.

From a total of 100 documents on software engineering and business, 734 keywords were identified. Figure 7, utilizing VOSviewer, displays a visualization of these keywords, including only those appearing at least four times, resulting in 26 frequently occurring keywords. These are categorized into four color-coded groups reflecting related research themes.

The red group encompasses keywords such as 'business information systems', 'business software', 'computer software', 'information systems', 'mathematical models', 'requirements engineering', and 'software engineering process', highlighting the technical aspects and applications of software in business information systems.

The green group includes 'commerce', 'education', 'electronic commerce', 'engineering education', 'project management', 'students', and 'teaching', emphasizing education's role in equipping individuals for project management and e-commerce within technical and business environments.

The yellow group features 'enterprise resource management', 'information services', 'information technology', 'software architecture', 'software engineering', and 'systems engineering', focusing on resource management, IT infrastructure, and software architecture vital for efficient business operations.

Lastly, the blue group with keywords like 'application programs', 'computer software selection and evaluation', 'object-oriented programming', 'process engineering', 'software design', and 'software process', illustrates the core technical aspects of software programming and design, highlighting the importance of development methodologies and practices.

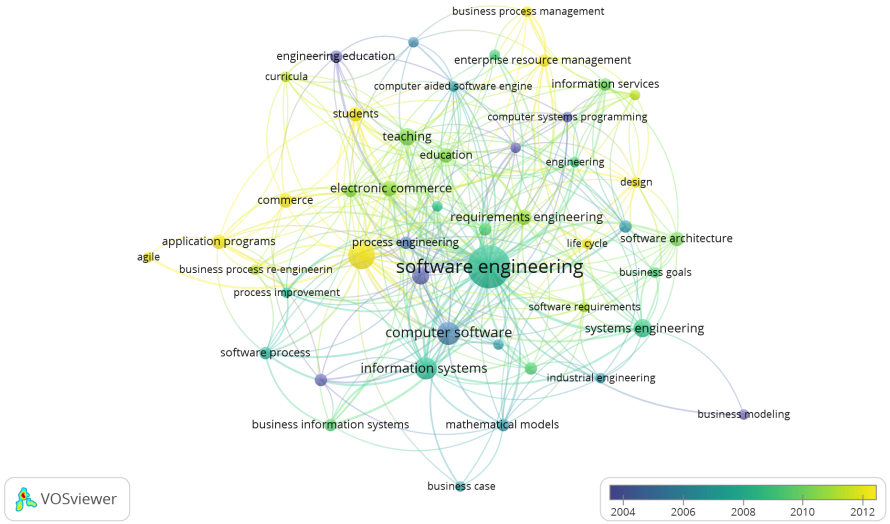

Figure 8. Overlay visualization.

Figure 8 displays an overlay visualization using the VOSviewer application, with criteria that only keywords appearing at least three times are included in the visualization. There are 47 frequently occurring keywords in the publications about software engineering and business. This visualization categorizes the keywords by color, which indicates the period of research time: purple for older research keywords, green for mid-period research keywords, and yellow for recent research keywords.

Keywords in the purple group include 'object-oriented programming,' 'process engineering,' 'computer software,' 'engineering education,' and 'business software,' marking them as foundational concepts in the early research of software engineering related to business. The green group, which includes 'requirements engineering,' 'teaching,' 'education,' and 'electronic commerce,' reflects the evolution and expansion of research focus towards education and electronic applications in business. Meanwhile, the yellow group, containing 'software design,' 'enterprise resource management,' 'students,' 'application programs,' 'commerce,' 'life cycle,' 'design,' 'business process management,' and 'agile,' mirrors current trends and innovations in research focusing more on design, management, and agile methodologies in software engineering for business.

Future researchers have the option to revisit old or mid-period topics, or to follow current trends in new keywords that are actively discussed within the academic and industry communities. This offers the opportunity to not only expand existing research but also innovate in creating relevant solutions for current business and technology challenges.

4) Future Research

From the VOSviewer visualization discussed previously, several additional keywords emerged as central to software engineering and business. These keywords can help future researchers expand and deepen their investigations, introducing innovative perspectives:

1. *Agile Methodologies*: Crucial for efficient software development through enhanced project management practices.
2. *User Experience (UX) Design*: Ensures that applications are effective and user-friendly.
3. *Data Science*: Utilizes mathematical models and IT to optimize decision-making and innovation.
4. *Cloud Computing*: Supports scalability and operational efficiency in business applications.
5. *Artificial Intelligence (AI)*: Integrates with software to automate and enhance business information systems.
6. *Cybersecurity*: Essential for protecting data and transactions in business-oriented software.
7. *Digital Transformation*: Connects engineering and commerce with ongoing digital shifts in industries.
8. *Sustainable Development*: Important for incorporating sustainability into software and business management.
9. *Blockchain Technology*: Increases transparency and security in digital transactions.
10. *Internet of Things (IoT)*: Expands connectivity and communication capabilities in business operations.

These keywords represent broad areas for developing new dimensions in software engineering research related to business, providing a more comprehensive and deeper understanding of the field.

D. Conclusion

Research in software engineering and business peaked in 2008 with 11 Scopus-indexed documents, focusing on the integration of software engineering in business contexts, analyzed bibliometrically. Gruhn, V., from Universität Leipzig, emerged as the leading author, contributing four publications and positioning Universität Leipzig as a key center of excellence. Both Germany and the United States were the most prolific, each producing 21 documents.

"Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics" was a major reference source with seven publications. Conference papers were the dominant publication format, emphasizing the role of academic forums in research dissemination. Computer Science was the principal subject, comprising nearly half of all publications, highlighting its role in integrating software engineering into business practices.

Co-keyword analysis with VOSviewer identified four main clusters, focusing on the integration of software architecture and information technology, software applications in business, the role of education in human resource development, and the importance of project and resource management. The year 2009 stood out for having the most impactful publications.

Future research opportunities lie in areas like Agile methodologies, UX design, data science, cloud computing, AI, cybersecurity, digital transformation, sustainability, blockchain technology, and IoT. These fields offer potential for further understanding how software engineering can be effectively integrated into business strategies to meet upcoming market and technology challenges.

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