Visual Analytics in Requirements Engineering: A Systematic Literature Review

Srimai Varikuti
School of Computing
University of North Florida
Jacksonville, USA
n01529664@unf.edu

Sandeep Reddivari
School of Computing
University of North Florida
Jacksonville, USA
n00959246@unf.edu

***Abstract*—The research on visual analytics (VA) for requirements engineering (RE) has noticeability advanced in the past few years. For many software projects, RE needs an effective and efficient path from data to decision. VA creates such a path that enables the user/requirements engineer to extract meaningful insights by interacting with the relevant requirements information. This paper focuses on VA for RE and has the following goals: investigate the VA adoption in RE and suggest important implications for practice, and identify most recent trends, open challenges, and opportunities. To achieve the goals, we performed a thorough review of literature from the past decade from 2010 to 2023 and assessed 35 studies to address three research questions. The survey results indicated that there is a lack of collaboration between RE researchers and practitioners.**

***Index Terms*—Requirements Engineering, Visual Analytics**

I. INTRODUCTION

Requirements Engineering (RE) plays a fundamental role in the software development lifecycle, ensuring that stakeholder needs are comprehensively captured, analyzed, and translated into specifications for successful system development [1]. Over time, the complexity and scale of systems have increased, amplifying the challenges in understanding, managing, and evolving requirements. In response to these challenges, Visual Analytics (VA) has emerged as a promising approach to support RE processes. VA involves the exploration, analysis, and presentation of data through interactive visual interfaces [2], leveraging computational techniques to aid sense-making and decision-making processes.

In the domain of RE, VA techniques offer the potential to enhance the comprehension and communication of complex requirements, facilitating a more intuitive understanding of diverse stakeholder needs and system constraints. The analysis structures key questions to investigate the presence of visual analytics approaches for RE [3], their techniques and application areas, the strength of empirical support, and gaps in current knowledge. Diverse tools are discussed such as requirement visualization frameworks, release planning dashboards, stakeholder concern mapping, and design rationale environments. The activities facilitated relate to planning, requirement modeling [4], managing technical debt, and improving stakeholder understanding. Despite the growing interest in VA for RE, the field lacks a comprehensive overview of existing research, methodologies, tools, and the impact of VA techniques. This systematic literature review aims to fill this gap by synthesizing and critically evaluating the current body of knowledge surrounding VA in RE.

This paper conducts a detailed study through a Systematic Literature Review (SLR) focusing on the VA in RE over the past decade from 2010 to 2023. By summarizing and analyzing relevant literature, this review aims to broaden our understanding of this specific area. SLRs involve a meticulous search process to ensure the inclusion of high-quality literature that provides substantial evidence for the review.

The goal of this research is to assess emerging tools, methods, evidence sources, and limitations to guide further research. The structure of the paper is as follows: Section 1 introduces the background information, Section 2 outlines the literature review process, Section 3 addresses the research questions posed in this study, Section 4 presents the discussion of the results, and finally, Section 5 provides the conclusion and future scope.

II. METHODOLOGY

A. Research Questions

This study aims to answer the following research questions:

RQ1. Are there existing any VA approaches, tools, or methods used in RE?

RQ1.1. What specific types of data are supported or visualized by these VA approaches or tools within the domain of RE?

RQ1.2. Which RE activities these VA tools address?

RQ1 and its sub-questions aim to structure the study by exploring and categorizing the landscape of VA tools/methods within RE. These inquiries offer valuable insights into the presence, diversity, and functionalities of VA approaches, delineating the supported data types and the specific activities addressed within the realm of RE.

RQ2. How much evidence is available to support the adoption of proposed VA techniques/methods in RE?

RQ2 will delve into the literature, adapting evidence assessment metrics to evaluate the robustness of proposed VA techniques/methods for RE. This study adapts the evidence assessment metrics proposed by Alves et al. [5]. Table I describes the scoring hierarchy for the evidence provided.

2835-5776/24/$31.00 ©2024 IEEE
DOI 10.1109/IRI62200.2024.00071

TABLE I
EVIDENCE ASSESSMENT METRICS HIERARCHY

Score	Meaning	Strength
0	No Evidence	Weakest
1	Evidence from Demonstrations	Weak
2	Evidence from Expert Opinion or Observation	Normal
3	Evidence from Academic Studies	Normal
4	Evidence from Industrial Studies	Strong
5	Evidence from Industrial Practice	Strongest

RQ3. What are the limitations of the current research in VA for RE?

RQ3 will explore the constraints and gaps in the existing research and provides a comprehensive understanding of the current state and potential areas for improvement in VA for RE.

B. Search Strategy

One of the important criteria to conduct a systematic literature review is a well-structured search strategy. Specific keywords encompassing "Visual Analytics," "Visualization," and "Visual Data Mining" were combined with terms relevant to "Requirements Engineering" to retrieve pertinent articles. The search strategy included both an automatic and a manual search. The automatic search was conducted on five electornic databases: IEEE Xplore, ACM Digital Library, Wiley, Science Direct and Springer Link. On the other hand, the manual search was conducted using Google Scholar. To ensure the currency of the selected literature, a filter was applied to include papers published between 2010 and 2023.

The search process involved a meticulous review of the top 100 results from each database. Furthermore, an additional 10 papers were manually chosen to guarantee a comprehensive selection of 35 papers for an in-depth analysis and synthesis of the current state of research at the intersection of VA and RE. Both search strategies uses the following search string:

> ("Visual Analytics" OR "Visualization" OR "Visual Data Mining") AND ("Requirements Engineering" OR "Software Requirements")

In total, 35 papers were used as primary literature in this study. As shown in Figure 2, 45% of the papers came from IEEE Xplore digital library. Followed by Spring Link and Science Direct with each 23 % and 16 % respectively. ACM and Wily makes up 16 % of the literature review.

C. Inclusion and Exclusion Criteria

This paper reviewed articles published on VA for RE based on the following criteria. Articles that meet the following criteria are included:

- Relevance to the Research Topic:
  To be considered for this systematic literature review, selected papers must directly pertain to the application of VA in the context of RE.
- Publication Range:
  Papers eligible for inclusion are limited to those published between the years 2010 and 2023. This specific time frame has been chosen to ensure the inclusion of recent and up-to-date literature.
- Peer-Reviewed Sources:
  Only papers originating from peer-reviewed and scholarly sources, including academic journals and conference proceedings, will be considered. This criterion is applied to maintain the academic rigor of the review.
  Articles were excluded from the review based on the following criteria:
  - Irrelevance:
    Papers that do not directly address VA within RE will be excluded from this review.
  - Publication Range:
    Papers published prior to 2010 will not be included in this review.
  - Non Peer-Reviewed Sources:
    Papers originating from non peer-reviewed sources, such as blogs or websites, will not be considered.
  - Duplicate Publications:
    In cases where multiple versions of the same paper exist, only the most recent and complete version will be considered for the review.

Figure 1 illustrates the paper search and selection process.

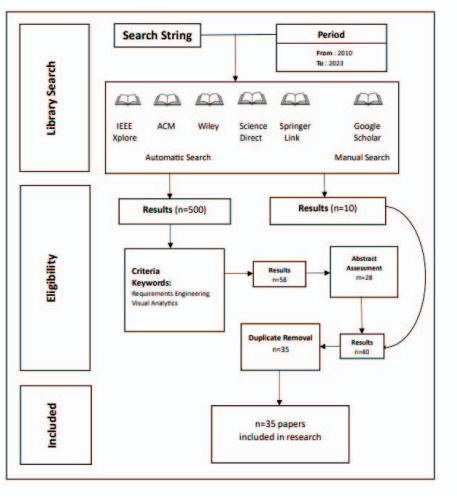

Fig. 1. Literature Search and Selection Process

III. RESULTS AND ANALYSIS

After conducting the search process as outlined in Section 2, each paper is reviewed to address each of the research questions. The following sections will describe and summarize the results.

RQ1. Are there any existing VA tools or methods that supports RE?

Within the domain of RE, a notable presence of VA techniques, tools, and methods has been identified through various literature sources. Several tools have been referenced, indicating the utilization of VA methods in handling the complexities

TABLE II
SELECTED PRIMARY LITERATURE USED IN THIS STUDY

ID	Title	Source	Search Process	
P1	Experience with user-centred requirements engineering	Springer Link	Manual	[6]
P2	STRATOS: Using Visualization to Support Decisions in Strategic Software Release Planning	ACM	Manual	[7]
P3	Visual notation design 2.0: Towards user comprehensible requirements engineering notations	IEEE	Manual	[8]
P4	Visualizing requirements in distributed system development	IEEE	Manual	[1]
P5	Requirements Engineering for Scientific Computing: A Model-Based Approach	IEEE	Manual	[9]
P6	VisLan: Using real options to manage Technical Debt in Requirements Engineering	IEEE	Manual	[3]
P7	SDVisu: Visualizing Stakeholder Concerns with Anchored Map	Springer Link	Manual	[10]
P8	Visual requirements analytics: a framework and case study	Springer Link	Manual	[11]
P9	DREAMER: a design rationale environment for argumentation, modeling and engineering requirements	ACM	Manual	[4]
P10	Visualizing non-functional requirements patterns	IEEE	Automatic	[12]
P11	Interactive goal model analysis for early requirements engineering	Springer Link	Automatic	[2]
P12	Agile Requirements Engineering: A systematic literature review	Science Direct	Automatic	[13]
P13	The use of a requirements modeling language for industrial applications	IEEE	Automatic	[14]
P14	Identifying relevant studies in software engineering	Science Direct	Automatic	[15]
P15	A Taxonomy and Visual Notation for Modeling Globally Distributed Requirements Engineering Projects	IEEE	Automatic	[16]
P16	Managing knowledge on communication and information flow in global software projects	Wiley	Automatic	[17]
P17	The Review for Visual Analytics Methodology	IEEE	Automatic	[18]
P18	Visual Analytics in Enterprise Architecture Management: A Systematic Literature Review	Science Direct	Automatic	[19]
P19	NORMATIC: A visual tool for modeling Non-Functional Requirements in agile processes	IEEE	Automatic	[20]
P20	Improved representation of traceability links in requirements engineering knowledge using Sunburst and Netmap visualizations	IEEE	Automatic	[21]
P21	A systematic literature review on agile requirements engineering practices and challenges	Science Direct	Automatic	[22]
P22	Multi Surface Interactions with Geospatial Data: A Systematic Review	ACM	Automatic	[23]
P23	Storytelling: The Next Step for Visualization	IEEE	Automatic	[24]
P24	Requirements engineering for software product lines: A systematic literature review	Science Direct	Automatic	[5]
P25	Requirements Engineering: Fundamentals, Principles, and Techniques	ACM	Automatic	[25]
P26	Keeping requirements on track via visual analytics	IEEE	Automatic	[26]
P27	Visual Analytics: A Comprehensive Overview	IEEE	Automatic	[27]
P28	Visual requirements analytics: a framework and case study	Springer Link	Automatic	[28]
P29	Requirements Engineering Visualization: A Systematic Literature Review	IEEE	Automatic	[29]
P30	Understanding user requirements in context: A case study of developing a visualisation tool to map skills in an engineering organisation	IEEE	Automatic	[30]
P31	Visualization for Software Product Lines: A Systematic Mapping Study	IEEE	Automatic	[31]
P32	On Systems of Systems Engineering: A Requirements Engineering Perspective and Research Agenda	IEEE	Automatic	[32]
P33	Emotions in Requirements Engineering: A Systematic Mapping Study	IEEE	Automatic	[33]
P34	A review of traceability research at the requirements engineering conferencere@21	IEEE	Automatic	[34]
P35	Visualizations for the evolution of Variant-Rich Systems: A systematic mapping study	Science Direct	Automatic	[35]

TABLE III
SOFTWARE TOOLS/TECHNIQUES FOUND IN SELECTED LITERATURE AND VISUALIZATION TECHNIQUES

Software/Technologies/Approaches	**Visualization Techniques**
STRATOS	Visualization for Strategic Software Release Planning
Visual Notation Design 2.0	User-Comprehensible Requirements Engineering Notations
Real Options	Managing Technical Debt in Requirements Engineering
Anchored Map	Visualizing Stakeholder Concerns
Visual Requirements Analytics Framework	Visual Requirements Analytics
DREAMER	Design Rationale Environment for Argumentation Modeling
Requirements Modelling Language	Industrial Applications of Requirements Modelling Language
NORMATIC	Modelling Non-Functional Requirements in Agile Processes
Sunburst, Netmap	Representation of Traceability Links in RE Knowledge

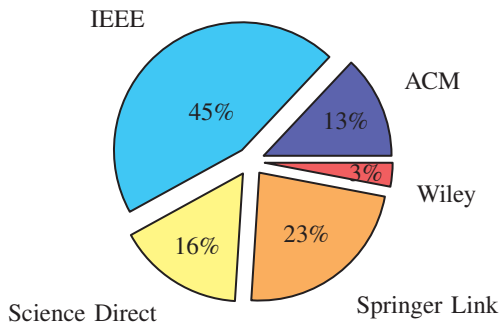

Fig. 2. Composition of Literature Sources

of RE. Table III displays the list of VA tools/techniques found in the selected literature. The visualization techniques employed by the tools are also outlined in the table.

Tools such as STRATOS [7], Visual Notation Design 2.0 [8] [16], Real Options, Anchored Map, Visual Requirements Analytics Framework, DREAMER, Requirements Modelling Language, NORMATIC, and Sunburst, Netmap have been mentioned across different studies. These tools signify a diverse spectrum of methodologies and approaches incorporating visualization techniques into the RE process.

RQ1.1. What specific types of data are supported or visualized by these VA tools within RE?

The VA approaches and tools utilized within RE demonstrate a broad capacity to handle and visualize various types of data. These tools cater to diverse data types including:
Strategic software release planning: Tools such as STRATOS [7] focus on visualization for strategic software release planning, enabling better decision-making and planning in the release process.

User-comprehensible requirements engineering notations: Visual Notation Design 2.0 emphasizes user-comprehensible notations [6], aiming to enhance the understanding and communication of requirements among stakeholders [10].

Management of technical debt in requirements: Real Options is utilized for managing technical debt in requirements engineering, assisting in identifying and mitigating technical debt issues.

Visualizing stakeholder concerns: Tools like Anchored Map are designed to visualize stakeholder concerns, facilitating a clearer understanding of stakeholder needs and concerns.

Design rationale environment for argumentation modeling: DREAMER provides a design rationale environment for argumentation modeling, aiding in capturing and modeling design discussions and rationale.

Industrial applications of requirements modeling language: Requirements Modelling Language tools are employed in industrial applications, suggesting a broader use of modeling languages for diverse requirements in industry settings.

Modeling non-functional requirements in agile processes: NORMATIC specializes in modeling non-functional requirements in agile processes, streamlining the integration of non-functional requirements [12] in agile methodologies.

Representation of traceability links in RE knowledge: Tools like Sunburst, Netmap focus on representing traceability links in Requirements Engineering knowledge, facilitating the traceability and understanding of relationships between various requirements artifacts

RQ1.2. Which RE activities these VA tools address?

The VA tools or techniques identified in the review address various RE activities such as requirements modeling, requirements traceability, requirements management and requirements visualization. Other activities include: *Strategic software release planning:* Tools like STRATOS [7] target strategic software release planning, aiding in the strategic decision-making process concerning software release schedules and planning.

Requirements visualization for stakeholders [10] understanding: Tools, such as Visual Notation Design 2.0, focuses on requirements visualization to enhance stakeholders [10] understanding of requirements, enabling better collaboration and communication.

Managing technical debt in requirements engineering: Real Options assists in managing technical debt in requirements engineering processes, allowing teams to handle and mitigate technical debt issues effectively.

Design rationale and argumentation modeling: Tools like DREAMER facilitate design rationale and argumentation modeling, enabling the capture and modeling of design discussions and the reasoning behind certain design decisions.

Modeling non-functional requirements in agile processes: NORMATIC specializes in modeling non-functional requirements in agile processes, aiding in the integration and management of non-functional [12] requirements in agile methodologies.

Traceability link representation in requirements knowledge: Tools such as Sunburst and Netmap target the representation of traceability links, assist in tracing and help understanding the relationships between various requirements artifacts, thus ensuring traceability across the requirements lifecycle.

RQ2: How much evidence is available to adopt proposed VA tools/techniques?

Each one of the literature's evidence was scored based on the metrics presented in Table I. As shown in Fig. 3, it is evident that there is a lack of evidence from the industry which is essential for the adaptation of these VA tools. Shakeri Hossein Abad et al. [24] presented a systematic review of Multi Surface Environments (MSE) interactions with geospatial data. It identifies limitations in the interaction with geospatial data in MSEs and highlights unexplored GIS tasks in these environments. Kosara and Mackinlay [24] emphasized the integration of storytelling elements into visualization as the next step in visualization research, alongside exploration

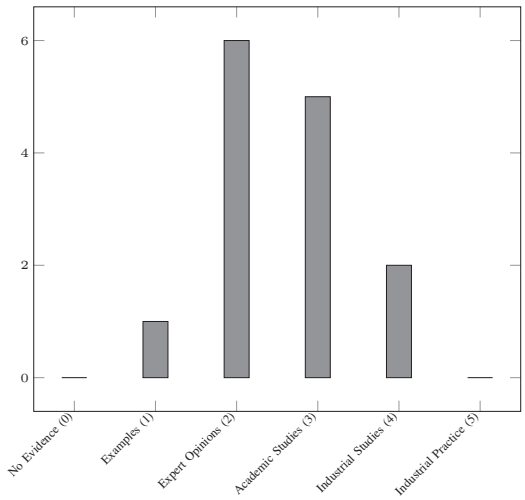

Fig. 3. Literature Evidence Evaluation

and analysis. Alves et al. [5] focused on Software Product Lines (SPLs) and conducted a systematic literature review on Requirements Engineering within SPLs. It aims to assess research quality, identify trends, and propose implications for practice. Pohl [25] provided a comprehensive introduction to the fundamentals, principles, and techniques of Requirements Engineering, offering validated procedures and industrial experience. Abad and Ruhe [26] discussed visual analytics to keep requirements on track in software projects, emphasizing the need for effective paths from data to decision-making through interactive information extraction. Cui [27] provided an overview of visual analytics, discussing its evolution, applications, challenges, and future directions across various domains dealing with big data analysis. Reddivari et al. [28] advanced the literature on visual requirements analytics [28], this paper introduces a framework and case study illustrating how increased interactivity in requirements visualization leads to actionable decisions. Abad et al. [29] reported the results of a systematic literature review on RE visualization, highlighting usage patterns and the need for more research on visualization support for specific RE activities. Joel-Edgar and Gopsill [30] presented a case study focusing on understanding the environment and work context of a visualization tool used in an engineering organization. Lopez-Herrejon et al. [31] conducted a systematic mapping study on visualization for Software Product Lines, aiming to identify trends, gaps, and opportunities for further research and application. Ncube and Lim [32] addressed the challenges posed by Systems of Systems (SoSs) and advocates for evolving current RE approaches to cope with their complexities. Thew and Sutcliffe [33] focused on value-based requirements engineering, providing a method for analyzing socio-political issues in the RE process. Nair et al. [34] Analyzed traceability research at the Requirements Engineering Conference, summarizing aspects addressed and proposing further research areas. Medeiros et al. [35] presented

a systematic mapping study on visualizations for the evolution of Variant-Rich Systems (VRS), discussing the challenges in VRS evolution and the need for visualization tools.

RQ3: What are the limitations of the current research in VA for RE?

The analysis of the provided papers revealed several limitations in the current research related to VA for RE:

Limited Empirical Validation: The majority of the papers focused on proposing new techniques or frameworks without substantial empirical validation through real-world applications or experiments. Studies by [25] and [35] provided comprehensive insights into requirements engineering but lacked empirical validation of proposed methods.

Sparse Coverage of Key Aspects: Gaps in the literature, such as inadequate coverage of specific phases of Requirements Engineering, were apparent. For instance, the research by [30] highlighted the need for understanding user requirements [6] but did not extensively delve into empirical validation.

Lack of Comparative Studies: Comparative analyses or studies benchmarking different Visual Analytics techniques in Requirements Engineering were relatively scarce. Relevant comparisons were limited, as seen in the work by [29], which addressed visualization support but lacked a comparative perspective.

Need for Standardization: The absence of standardized evaluation metrics or guidelines for assessing the efficacy and usability of Visual Analytics methods in Requirements Engineering posed challenges in evaluating and comparing different approaches. Notably, [5] conducted a systematic literature review to assess research quality but didn't propose standardized metrics for evaluation.

Limited Scalability or Adaptability: Some techniques demonstrated limitations in scalability or adaptability, especially when handling large-scale or diverse sets of requirements effectively. Cui [27] emphasized the challenges in gaining useful information from massive data, indicating limitations in scalability despite advancements in visual analytics.

The identified limitations underscore the need for further empirical validation, broader coverage, comparative studies, standardization efforts, and enhancements in scalability for VA for RE.

IV. Discussion

This section presents the main findings and limitations of this study.

A. Main Findings

Limited Exploration in Multi-Surface Environments (MSEs): Shakeri Hossein Abad et al. [23] highlighted the scarcity of research investigating interactions with geospatial data in Multi-Surface Environments (MSEs). The study underscored design and interaction issues, emphasizing the significance of exploring Geographic Information Systems (GIS) tasks within MSEs.

Visualization in Requirements Engineering: Abad et al. [3], explored visualization techniques in Requirements Engineering. They outlined frameworks [11], case studies, and systematic literature reviews, emphasizing the potential of visual analytics in improving decision-making, requirements tracing, and risk assessment.

Challenges in Systems of Systems (SoSs) Engineering: Ncube and Lim [32] emphasized the increasing complexity of Systems of Systems (SoSs) and the limitations of current RE practices to handle these complexities. The study proposed the evolution of RE approaches and the development of new RE capabilities to address the challenges posed by SoSs.

Visualization Support in Software Product Lines (SPLs): Lopez-Herrejon et al. [31] conducted a systematic mapping study on Software Product Lines (SPLs), demonstrating the application of visualization techniques across the SPL life cycle. The study aimed to identify trends, gaps, and opportunities for further research and application in this domain.

Value-Based Requirements Engineering: Thew and Sutcliffe [33] introduced a method for analyzing socio-political issues, values, motivations, and emotions in RE. Their validation studies supported the acceptability and effectiveness of the method for industrial practitioners [14].

B. Limitations of the Study

Lack of Empirical Validation: Many studies proposed frameworks, conceptual ideas, or systematic reviews without substantial empirical validation through real-world applications or experiments. For instance, [25] presented comprehensive principles and techniques of RE but lacked empirical validation of the proposed methods.

Sparse Coverage and Comparative Analyses: Gaps were observed in the literature, including limited coverage of specific phases of RE and a lack of comparative studies benchmarking different techniques. For example, the study by [6] addressed the need for understanding user requirements however they have not extensively explored empirical validation.

Need for Standardization and Scalability: The absence of standardized evaluation metrics, guidelines, and challenges in scalability for handling large-scale requirements datasets were prevalent across various studies. Cui [27] highlighted the challenges in gaining useful insights from massive data, indicating limitations in scalability despite advancements in visual analytics.

Focus on Specific Aspects: Some studies focused primarily on specific aspects (e.g., geospatial data, value-based analysis) within RE, potentially limiting the broader applicability and generalization of findings to other domains or phases of RE.

Research Gaps and Unexplored Areas: Despite the wealth of studies, there were clear indications of research gaps in specific RE activities like requirements uncertainty, verification, modeling [4], and non-functional requirements (NFRs) visualization [29].

V. Conclusion and Future Scope

In this research, we conducted a systematic literature review on VA for RE and investigated the three research questions that

were posed. To that end, we conducted a thorough review of literature from the past decade from 2010 to 2023 to explore how integrating VA into RE can improve its efficiency and effectiveness.

The study reveals that while there is no shortage of advancement in new VA tools, techniques and meth- ods, there needs to be a collaboration between RE researchers and industry practitioners. The trend of VA for RE is currently growing towards visual data mining, interactive visualizations, 3D graphics and visual clustering. Further studies are needed to expand to more RE activities. Since only a small number of articles were surveyed, we plan to expand the search query and conduct a more robust systematic literature review on VA for RE.

REFERENCES

[1] D. Savio, P. Anitha, A. Patil, and O. Creighton, "Visualizing requirements in distributed system development," in *2012 Second IEEE International Workshop on Requirements Engineering for Systems, Services, and Systems-of-Systems (RESS)*. IEEE, 2012, pp. 14–19.

[2] J. Horkoff and E. Yu, "Interactive goal model analysis for early requirements engineering," *Requirements Engineering*, vol. 21, pp. 29–61, 2016.

[3] Z. S. H. Abad and G. Ruhe, "Using real options to manage technical debt in requirements engineering," in *2015 IEEE 23rd international requirements engineering conference (RE)*. IEEE, 2015, pp. 230–235.

[4] C. Martinie, P. Palanque, M. Winckler, and S. Conversy, "Dreamer: a design rationale environment for argumentation, modeling and engineering requirements," in *Proceedings of the 28th ACM International Conference on Design of Communication*, 2010, pp. 73–80.

[5] V. Alves, N. Niu, C. Alves, and G. Valença, "Requirements engineering for software product lines: A systematic literature review," *Information and Software Technology*, vol. 52, no. 8, pp. 806–820, 2010.

[6] A. Sutcliffe, S. Thew, and P. Jarvis, "Experience with user-centred requirements engineering," *Requirements Engineering*, vol. 16, pp. 267–280, 2011.

[7] B. A. Aseniero, T. Wun, D. Ledo, G. Ruhe, A. Tang, and S. Carpendale, "Stratos: Using visualization to support decisions in strategic software release planning," in *Proceedings of the 33rd annual ACM conference on human factors in computing systems*, 2015, pp. 1479–1488.

[8] P. Caire, N. Genon, P. Heymans, and D. L. Moody, "Visual notation design 2.0: Towards user comprehensible requirements engineering notations," in *2013 21st IEEE International Requirements Engineering Conference (RE)*. IEEE, 2013, pp. 115–124.

[9] Y. Li, M. Harutunian, N. Narayan, B. Bruegge, and G. Buse, "Requirements engineering for scientific computing: A model-based approach," in *2011 IEEE Seventh International Conference on e-Science Workshops*. IEEE, 2011, pp. 128–134.

[10] T. Ugai, "Visualizing stakeholder concerns with anchored map," in *Human Interface and the Management of Information. Interacting with Information: Symposium on Human Interface 2011, Held as Part of HCI International 2011, Orlando, FL, USA, July 9-14, 2011, Proceedings, Part I*. Springer, 2011, pp. 268–277.

[11] S. Reddivari, S. Rad, T. Bhowmik, N. Cain, and N. Niu, "Visual requirements analytics: a framework and case study," *Requirements engineering*, vol. 19, pp. 257–279, 2014.

[12] S. Supakkul and L. Chung, "Visualizing non-functional requirements patterns," in *2010 Fifth International Workshop on Requirements Engineering Visualization*. IEEE, 2010, pp. 25–34.

[13] E.-M. Schön, J. Thomaschewski, and M. J. Escalona, "Agile requirements engineering: A systematic literature review," *Computer standards & interfaces*, vol. 49, pp. 79–91, 2017.

[14] B. Berenbach, F. Schneider, and H. Naughton, "The use of a requirements modeling language for industrial applications," in *2012 20th IEEE International Requirements Engineering Conference (RE)*. IEEE, 2012, pp. 285–290.

[15] H. Zhang, M. A. Babar, and P. Tell, "Identifying relevant studies in software engineering," *Information and Software Technology*, vol. 53, no. 6, pp. 625–637, 2011.

[16] P. Laurent, P. Mäder, J. Cleland-Huang, and A. Steele, "A taxonomy and visual notation for modeling globally distributed requirements engineering projects," in *2010 5th IEEE International Conference on Global Software Engineering*. IEEE, 2010, pp. 35–44.

[17] K. Stapel and K. Schneider, "Managing knowledge on communication and information flow in global software projects," *Expert Systems*, vol. 31, no. 3, pp. 234–252, 2014.

[18] Z. Ahmad, S. Yaacob, R. Ibrahim, and W. F. W. Fakhruddin, "The review for visual analytics methodology," in *2022 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*. IEEE, 2022, pp. 1–10.

[19] D. Jugel, K. Sandkuhl, and A. Zimmermann, "Visual analytics in enterprise architecture management: a systematic literature review," in *Business Information Systems Workshops: BIS 2016 International Workshops, Leipzig, Germany, July 6-8, 2016, Revised Papers 19*. Springer, 2017, pp. 99–110.

[20] W. M. Farid and F. J. Mitropoulos, "Normatic: A visual tool for modeling non-functional requirements in agile processes," in *2012 proceedings of IEEE Southeastcon*. IEEE, 2012, pp. 1–8.

[21] T. Merten, D. Jüppner, and A. Delater, "Improved representation of traceability links in requirements engineering knowledge using sunburst and netmap visualizations," in *2011 4th International Workshop on Managing Requirements Knowledge*. IEEE, 2011, pp. 17–21.

[22] I. Inayat, S. S. Salim, S. Marczak, M. Daneva, and S. Shamshirband, "A systematic literature review on agile requirements engineering practices and challenges," *Computers in human behavior*, vol. 51, pp. 915–929, 2015.

[23] Z. Shakeri Hossein Abad, C. Anslow, and F. Maurer, "Multi surface interactions with geospatial data: A systematic review," in *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces*, 2014, pp. 69–78.

[24] R. Kosara and J. Mackinlay, "Storytelling: The next step for visualization," *Computer*, vol. 46, no. 5, pp. 44–50, 2013.

[25] K. Pohl, *Requirements Engineering: Fundamentals, Principles, and Techniques*, 1st ed. Springer Publishing Company, Incorporated, 2010.

[26] N. Niu, S. Reddivari, and Z. Chen, "Keeping requirements on track via visual analytics," in *2013 21st IEEE International Requirements Engineering Conference (RE)*. IEEE, 2013, pp. 205–214.

[27] W. Cui, "Visual analytics: A comprehensive overview," *IEEE access*, vol. 7, pp. 81 555–81 573, 2019.

[28] S. Reddivari, S. Rad, T. Bhowmik, N. Cain, and N. Niu, "Visual requirements analytics: a framework and case study," *Requirements engineering*, vol. 19, pp. 257–279, 2014.

[29] Z. S. H. Abad, M. Noaeen, and G. Ruhe, "Requirements engineering visualization: a systematic literature review," in *2016 IEEE 24th International Requirements Engineering Conference (RE)*. IEEE, 2016, pp. 6–15.

[30] S. Joel-Edgar and J. Gopsill, "Understanding user requirements in context: a case study of developing a visualisation tool to map skills in an engineering organisation," in *2018 International Conference on Information Management and Processing (ICIMP)*. IEEE, 2018, pp. 6–10.

[31] R. E. Lopez-Herrejon, S. Illescas, and A. Egyed, "Visualization for software product lines: A systematic mapping study," in *2016 IEEE Working Conference on Software Visualization (VISSOFT)*. IEEE, 2016, pp. 26–35.

[32] C. Ncube and S. L. Lim, "On systems of systems engineering: A requirements engineering perspective and research agenda," in *2018 IEEE 26th International Requirements Engineering Conference (RE)*. IEEE, 2018, pp. 112–123.

[33] S. Thew and A. Sutcliffe, "Value-based requirements engineering: method and experience," *Requirements engineering*, vol. 23, pp. 443–464, 2018.

[34] S. Nair, J. L. De La Vara, and S. Sen, "A review of traceability research at the requirements engineering conference re@ 21," in *2013 21st IEEE International Requirements Engineering Conference (RE)*. IEEE, 2013, pp. 222–229.

[35] R. Medeiros, J. Martinez, O. Díaz, and J.-R. Falleri, "Visualizations for the evolution of variant-rich systems: A systematic mapping study," *Information and Software Technology*, vol. 154, p. 107084, 2023.