A Review and Analysis of Tools Used from 2018 till 2022 in Requirements Engineering

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Abstract. The commonly known stages in Requirements Engineering (RE) include planning, elicitation, documentation, validation, and management. Each stage consists of multiple processes and activities between stakeholders that result in data collection and analysis. Activities and data can be collected/extracted/analysed by manual or automated software tools to streamline the requirements engineering process. The objective of this review is to collate and study the distribution of tools in each stage and to discover missing gaps (if any) in tools for each stage. An electronic search was conducted on four publication libraries to compile all tools introduced in the requirements engineering field from 2018 to April 2022. 33 publications were found, and data extraction was performed on them to classify the tools to discover common patterns and methodologies. The results from data analysis showed that most new tools focused on elicitation and validation stages of RE. Planning and documentation stages had the least number of new tools. No new methodologies for RE tool creation were introduced. NLP remained the popular approaches among researchers. 21 out of 33 publications did not present case studies to prove the practical applications of the tools they introduced. This review has aggregated knowledge in the tools used in different RE stages.

Keywords: Software tool · Requirements engineering · Literature review

1 Introduction

In any software development methodology, requirements engineering remains the core stage of a software lifecycle. Requirements engineering (RE) is the process of discovering stakeholders' requirements and documenting them in such a way that they can serve as a reference for system development [35]. There are five commonly known stages in RE: planning, elicitation, documentation, validation, and management. Despite new technologies and systems being developed, these five stages remain fundamentally the same.

The process of requirements engineering can be done manually or aided with a tool. The usage of a tool may be manually triggered or automated. Definition of 'tool' in the scope of this review is a software or utility that can be used to ease or automate a routine process. 'Tool' in this sense encompasses manually triggered or automated

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tools. Algorithms and methodologies with no means of producing an output were not considered in this scope. Due to the predictable and unchanging stages of requirements engineering, a review on recent tools that aid the process of requirements engineering is considered for this purpose.

2 Related Work

The focus of this study is on new tools created to support requirements engineering stages. In [28], a critical analysis of tools, techniques and methodologies has been performed. However, the results were only focused on the elicitation stage despite its objective of covering the entire requirements engineering process. The resultant analysis of tools was too general and vague with no mention of any specific tools.

Reference [34] presented a systematic review of requirements engineering tools published between 2013 to 2018. The outcome of their review was categorizing tools according to requirements engineering stages. It was noted by the researcher that most requirements engineering tools focused on functional requirements, whilst neglecting quality attributes and only two tools were used in industries.

A comparison of requirements management software from 2003 to 2019 was done in [27]. 13 articles were shortlisted that contained 63 requirements management software. The researcher identified 15 set of features and applied priority weights to them and concluded with a feature scoring of the tools reviewed.

3 Method

The method for this review is summarized as below:

- Formulate several research questions to address the topic of this review
- Search for publications fitting filter criteria in digital libraries and compile the results
- Read through the abstracts of each publication and exclude based on exclusion criteria
- Read and extract information from shortlisted publications.
- Verify case studies where applicable
- Consolidate and analyze list of tools
- Formulate conclusion based on analysis.

3.1 Research Question

Three research questions have been tabled by this study:

RQ1. How many new requirements engineering tools have been created since 2018?

RQ2. At which stages of requirements engineering are the tools focused on?

RQ3. Are there any new methodologies introduced to aid in requirements engineering?

With respect to all three research questions, all stages of requirements engineering were identified, and a systematic search of related literature for each stage was conducted.

3.2 Data Sources

The sources of digital libraries selected for this review are Google Scholar, SpringerLink, ACM Library and IEEE Xplore Digital Library.

3.3 Search Strategy

This study was conducted in the month of March 2022. The keyword searches used are as below:

- Requirements engineering tool
- Requirements engineering automation
- Automated requirements engineering
- Requirements engineering survey tool
- Requirement engineering brainstorming tool
- Creative requirement tool
- Requirement engineering documentation tool
- Requirement engineering observation tool
- Requirement engineering validation tool
- Requirements engineering management.

All the keywords were used on searches performed on every data source listed. Double quotes were used to ensure more relevant search results. Every page in the search batches was traversed until the search results were observed to be deviating from the research topic. It was discovered that omitting the word "tool" during search yielded more effective results.

Inclusion criteria of tools that qualify for this systematic review were:

- English language publications produced between 2018 and 2022
- Empirical research paper related to software engineering
- Research affects at least one stage of RE
- End result of research paper is a tool or methodology that improves/assists/supports the RE stage in a beneficial way.

3.4 Exclusion Criteria

This study focused on production-ready RE tools that can actually be applied on case studies. The abstract must be related to at least one RE stage and if no specific tool was mentioned, the rest of the publication is scoured to find this detail. Therefore, publications that dealt in methodology and improvement of algorithm were not included in the final results. Publications that were too general and cannot be classified as a tool were also discarded.

Based on the search keywords, 33 publications were shortlisted. One publication was discarded due to the exclusion criteria and another excluded due to invalid URL to a key reference that contained case study industry information.

3.5 Data Extraction

Data extraction was performed on 25 shortlisted publications and the following attributes recorded in Microsoft Excel:

- Title
- Author name
- Year of publication
- Methodology used to develop tool
- Usage of machine learning
- Case study if available
- Targeted industry for tool
- Publication URL
- Affected RE stage.

Classification of tools into their respective RE stages was done by reviewing each publication and categorizing them according to the stages mentioned by their authors. No tools were found with overlapping stages.

4 Results

Results of the data extraction are shown in Table 1. In summary, the breakdown of new tools created since 2018 for each requirements engineering stage is depicted in Table 2.

5 Discussion

The three research questions that this review seeks to address are answered in this section.

***RQ1.* How many new requirements engineering tools have been created since 2018?**

There are 33 manual and automated requirements engineering tools found. 4 out of the 33 (12.1%) tools used machine learning as its approach to support the requirements engineering process. 15 out of the 33 (45.4%) utilized natural language processing in various stages of requirements engineering. 12 out of 33 (36.3%) tools were proven and backed by case studies to prove their effectiveness.

RQ2. At which stages of requirements engineering are the tools focused on?

It can be observed that there is a lack of tools in the planning and documentation stage of requirements engineering. The reason to this may be attributed to the fact that the planning and documentation of requirements engineering can be generalized and there are pre-existing mature and stable tools in these stages that have been introduced before 2018 (Fig. 1).

A majority of new tools focus on elicitation and validation. Both stages have almost the same number of tools and implement similar methodologies. There is a lack of focus on tools that support observation and creative techniques in elicitation.

Table 1. Result of data extraction that have introduced requirements engineering tools from 2018 to April 2022

Ref. No.	Paper Title	RE Stage	Methodology	Machine Learning	Case Study
[1]	"Requirements-Collector: Automating Requirements Specification from Elicitation Sessions and User Feedback"	Elicitation	Deep learning and machine learning	Yes	None
[2]	"DBRG: Description-Based Non-Quality Requirements Generator"	Validation	Prolog variable binding approach	No	None
[3]	"MAANA: An Automated Tool for DoMAin-specific Handling of Ambiguity"	Validation	Natural Language Processing	No	None
[4]	"piStar Tool—A Pluggable Online Tool for Goal Modeling"	Planning	i* modelling language	No	None
[5]	"RM2PT: A Tool for Automated Prototype Generation from Requirements Model"	Validation	Requirement to code matrices modeler and OCL parser	No	Supermarket System (CoCoME), Library Management System (LibMS), Automated Teller Machine (ATM), and Loan Processing System (LoanPS)
[6]	"NERO: A Text-based Tool for Content Annotation and Detection of Smells in Feature Requests"	Validation	Fuzzy comprehensive evaluation (FCE) method and the analytic hierarchy process (AHP)	No	None

(*continued*)

Table 1. (*continued*)

Ref. No.	Paper Title	RE Stage	Methodology	Machine Learning	Case Study
[7]	"ELICA: An Automated Tool for Dynamic Extraction of Requirements Relevant Information"	Validation	Natural Language Processing	No	Ticketing system
[8]	"Prema: A Tool for Precise Requirements Editing, Modeling and Analysis"	Validation	Compiler and parser generator	No	Automatic train protection system
[9]	"TreeTagger parser automatic Transformation of User Stories into UML Use Case Diagrams using NLP Techniques"	Elicitation	NLP	No	WebCompany
[10]	"DoMoBOT: A Modelling Bot for Automated and Traceable Domain Modelling"	Planning	NLP and supervised ML	Yes	None
[11]	"Enhancing Automated Requirements Traceability by Resolving Polysemy"	Management	Latent semantic indexing (LSI)	Yes	None
[12]	"SReYantra: Automated Software Requirement InterDependencies Elicitation, Analysis and Learning"	Elicitation	NLP	No	None
[13]	"Automated Identification of Type-Specific Dependencies Between Requirements"	Elicitation	NLP	No	None
[14]	"TraceRefiner: An Automated Technique for Refining Coarse-Grained Requirement-to-Class Traces"	Management	Requirement to code matrices	No	Chess, Gantt, and JHotDraw

(*continued*)

In the planning stage of requirements engineering, it is important to represent real world ideas and flow quickly. Modelling tools aid the understanding of new functionality and provide a quick overview to newcomers. Two RE planning stage tools were

Table 1. (*continued*)

Ref. No.	Paper Title	RE Stage	Methodology	Machine Learning	Case Study
[15]	"Automated cloud servicebased quality requirement classification for software requirement specification"	Elicitation	Deep Learning	Yes	None
[16]	"AN AUTOMATED APPROACH TO VALIDATE REQUIREMENTS SPECIFICATION"	Validation	Use case diagram based on UML	No	Online shopping
[17]	"FAME: Supporting Continuous Requirements Elicitation by Combining User Feedback and Monitoring"	Elicitation	Ontology	No	Energy efficiency management
[18]	"GeekyNote: A Technical Documentation Tool with Coverage, Backtracking, Traces, and Couplings"	Documentation	Annotation	No	Test automation and GUI automation, software robot based on image processing
[19]	"GuideGen - A Tool for Keeping Requirements and Acceptance Tests Aligned"	Management	Stanford sentence splitting algorithm	No	Access control and security solution, IT integration and cloud services, automation for warehouse and distribution center

(*continued*)

introduced. [10] focused on domain modelling while [4] specialized in i* goal modelling. Both tools ease the laborious and time-consuming process of model generation for analysis. [10] used traceability knowledge graph as an approach while [4] extended the i* 2.0 language to support goal-oriented modelling.

Table 1. (*continued*)

Ref. No.	Paper Title	RE Stage	Methodology	Machine Learning	Case Study
[20]	"The Interactive Narrator Tool: Effective Requirements Exploration and Discussion through Visualization	Elicitation	NLP	No	No
[21]	"UCAnalyzer: A Tool to Analyze Use Case Textual Descriptions"	Validation	Natural Language Toolkit	No	No
[22]	"ITBox: Pinpointing Ambiguity and Incompleteness in Requirements Engineering via Information Visualization and NLP"	Management	Templates and libraries	No	No
[23]	"Semi – Automated Software Requirement Specification (SRS) Document Generator: The Guideline to Novice System Analyst"	Documentation	SRS document automator framework	No	No
[24]	"An Idea Generation Tool for Designing Behavior Change Games"	Elicitation	Idea Generation Card Game	No	No
[25]	"Smart3E: Enabling End Users to Express Their Needs for Smart Homes DSIGS"	Elicitation	Template-based language	No	No
[26]	"Introducing TRAILS: A tool supporting traceability, integration and visualisation of engineering knowledge for product service systems development"	Management	Semantic model integration Ontology	No	Bike sharing system

(*continued*)

The requirements elicitation stage is a complex process that consists of processes such as gathering product requirements from stakeholders. Most tools introduced since 2018 focused on eliciting requirements from user via user feedback and user stories [1,

Table 1. (*continued*)

Ref. No.	Paper Title	RE Stage	Methodology	Machine Learning	Case Study
[27]	"Requirements Traceability Management Support Tool for UML Models"	Management	UML Modeling	No	No
[28]	"A Domain-Specific Language to manage Requirements Traceability"	Management	Structured NL (ReqNL)	No	No
[29]	A Qualitative Study on using GuideGen to Keep Requirements and Acceptance Tests Aligned	Management	NLP	No	Online shopping, CMS, Security
[30]	"Towards Development of Complete and Conflict-Free Requirements"	Documentation	Ontology	No	Aviation system
[31]	"CARO: A Conflict-Aware Requirement Ordering Tool for DevOps"	Validation	Requirements Ordering Algorithm	No	No
[32]	"RV-SLC: A Tool for Regression Validation of Safety and Liveness Constraints on Goal Models in DevOps Environment"	Validation	Model based	No	No
[33]	"Poster: Automatic Consistency Checking of Requirements with ReqV"	Validation	Property Specification Pattern (semantics)	No	No

9]. Some tools used natural language processing to automatically extract feedback into formal documents

References [12, 13, 20, 25]. Other tools classified requirements using machine learning [15].

Table 2. Results of Data Extraction

RE stage	Publications
Planning	[4, 10]
Elicitation	[1, 9, 12, 13, 15, 17, 20, 24, 25]
Documentation	[18, 23, 30]
Validation	[2, 3, 5–8, 16, 21, 31, 32, 33]
Management	[11, 14, 19, 22, 26, 27, 28, 29]

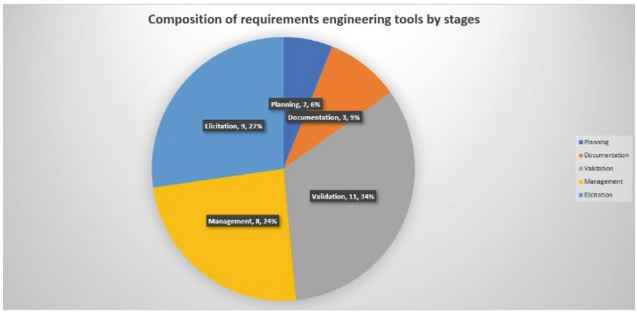

Fig. 1. Composition of requirements engineering tools published from 2018–April 2022 by RE stage

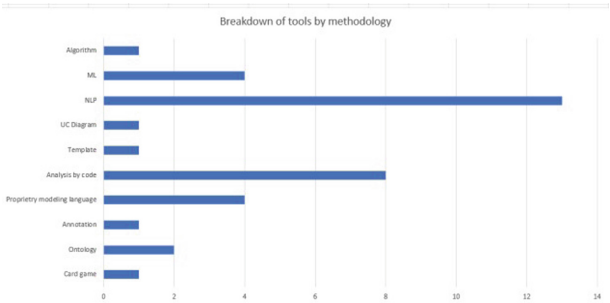

Fig. 2. Breakdown of tool methodology

According to [26], requirements validation is the process of eliminating ambiguities and inconsistencies in the SRS. This is implemented via requirements inspections, prototyping and testing. Eleven publications were found that highlighted requirements validation tools. Some tools detect feature smells in requests [6] and analyzes use-case diagrams [16] for inconsistencies. The process of analysis and detection were implemented using natural language processing [3, 21, 33] and machine learning. Automatic prototyping was another tool produced as a springboard and requirement visualizer (Fig. 2).

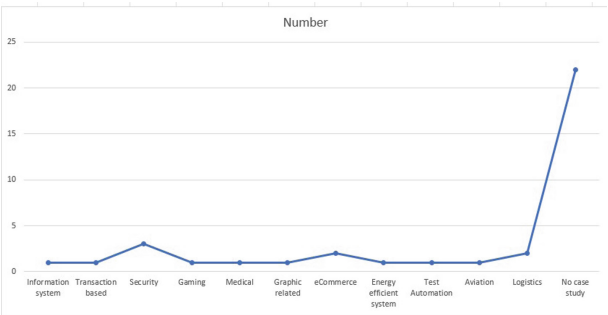

Fig. 3. RE tools case studies.

The final stage of requirements engineering is requirements management. Requirements management typically includes change management for requirements, requirements traceability, collaboration with relevant stakeholders, and approvals of requirements.

5 out of 8 tools found at management stage were tools that focused on traceability of requirements. As traceability of requirements translates to efficient usage of resources and time in the long run, there is a demand for tools in this area.

RQ3. Are there any new methodologies introduced to aid in requirements engineering?

Based on the search results, there were no new methodologies introduced in requirements engineering tools. A majority of the tools researched were utilizing known methodologies such as NLP and machine and deep learning with customization based on the targeted platform. A notable mention is [24] that proposed a nonsoftware approach to generate idea via card games.

From the results of this study, the low number of new tools in requirements engineering may be due to the unidirection of requirements engineering stages. Although planning, elicitation and validation are iterative processes, the unique nature of each industry in software development makes the creation of a universal catch-all tool a challenge. This is demonstrated in Fig. 3 where 63.6% of the new requirements engineering tools introduced were not tested with case studies, while tools that reported case studies performed them in different industry sectors. The effort vs ROI does not justify the development of an enterprise-level requirements engineering tool that could fit each industry sector.

6 Conclusion

This paper has presented a literature review of manual and automated tools used in requirements engineering. The results obtained showed different tools created for different stages of requirements engineering. No one tool overlapped in stages but focused solely in one requirements stage. There were more tools created for requirements elicitation and validation compared to requirements planning and management.

NLP and code-based code analysis make up the top two approaches in tool creation. The target industries used for case studies in proving the tools' effectiveness varied greatly.

It was identified that requirements planning and requirements management are RE stages that lack in the number of supporting tools and are therefore RE stages with the most room for growth and development of new tools. This review reached the same conclusion as Cadena-Romero [34] that not many industries are making use of RE tools in real-life scenarios. In order to increase tool effectiveness and acceptance, more case studies in popular and trending industries need to be conducted to increase users' confidence. This review has aggregated knowledge in the tools used in different RE stages.

Paradoxically, although machine learning technique is used extensively in the actual development of software; it's minimal application in requirements engineering tools was an interesting observation. [36] noted that the major challenge of using ML approach in requirements engineering was the lack of relevant datasets. This contributing factor is similar to the analysis of RQ3. Every industry requirement is unique and will require different datasets pertaining to their area.

Nevertheless, this review was limited by the number of papers found by means of online search in four popular digital libraries. Papers published in subscription-based journals and commercially developed tools were not taken into consideration. The compilation and analysis of results were performed with the assumption that the time and effort spent on each RE stage is distributed equally. However, in practice, this is often not the case.

This review was conducted from a broad and general perspective of requirements engineering. It has grouped RE tools created in the past five years by stages, methodology and industries in the hopes to gain valuable insights on what is lacking in each area. Future research could be devoted to finding similarities or identifying common attributes of specific RE stages across multiple industry sectors in an attempt to create a universal stagespecific RE tool.

Another aspect for future work includes performing detailed analysis by drilling into specific features of tools and focusing on the attributes of each RE stage to discover new trends and approaches of RE tools creation and to phase out outdated and less efficient tools.

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