SWARM-SLR – Streamlined Workflow Automation for Machine-actionable Systematic Literature Reviews

24.09.2024 • Tim Wittenborg • L3S Research Center, Hannover

available online,
same QR code
on all slides

L3S

Leibniz Universität Hannover

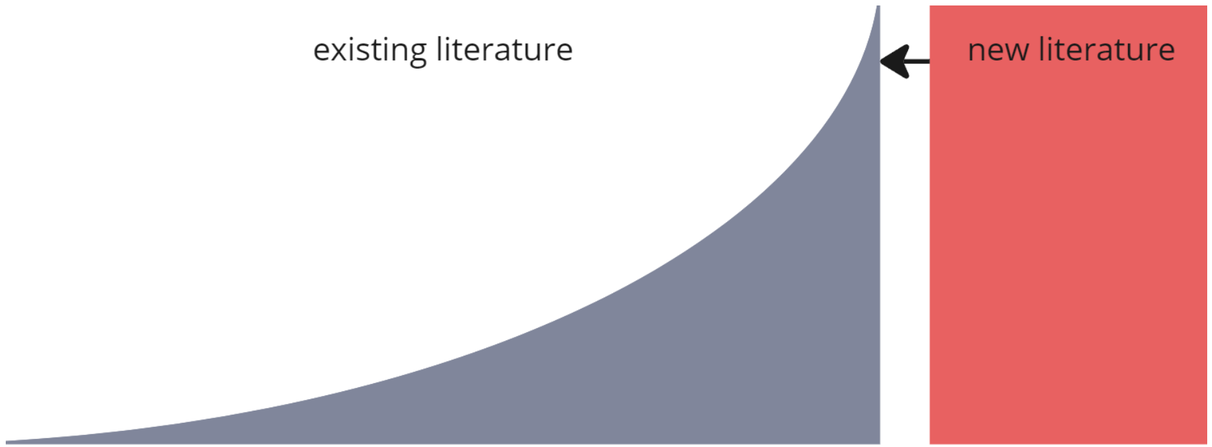
TIB LEIBNIZ-INFORMATIONSZENTRUM TECHNIK UND NATURWISSENSCHAFTEN UNIVERSITÄTSBIBLIOTHEK

Problem:

Too many publications

- Millions of new publications each year at a steadiliy increasing trend [1]

➢ **Solution:** efficient literature review support



Too many tools

- Hundreds of tools supporting different tasks without overview or cohesion [2]

➢ **Solution:** streamlined workflow automatization

[1] Bornmann, L., Mutz, R.: Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. Journal of the Association for Information Science and Technology 66(11), 2215–2222 (2015). https://doi.org/10.1002/asi.23329
[2] Bosman, J., Kramer, B.: 400+ Tools and innovations in scholarly communication - data collection forms (2023), https://docs.google.com/spreadsheets/d/1KUMSeq_Pzp4KveZ7pb5rddcssk1XBTiLHniD0d3nDqo/edit

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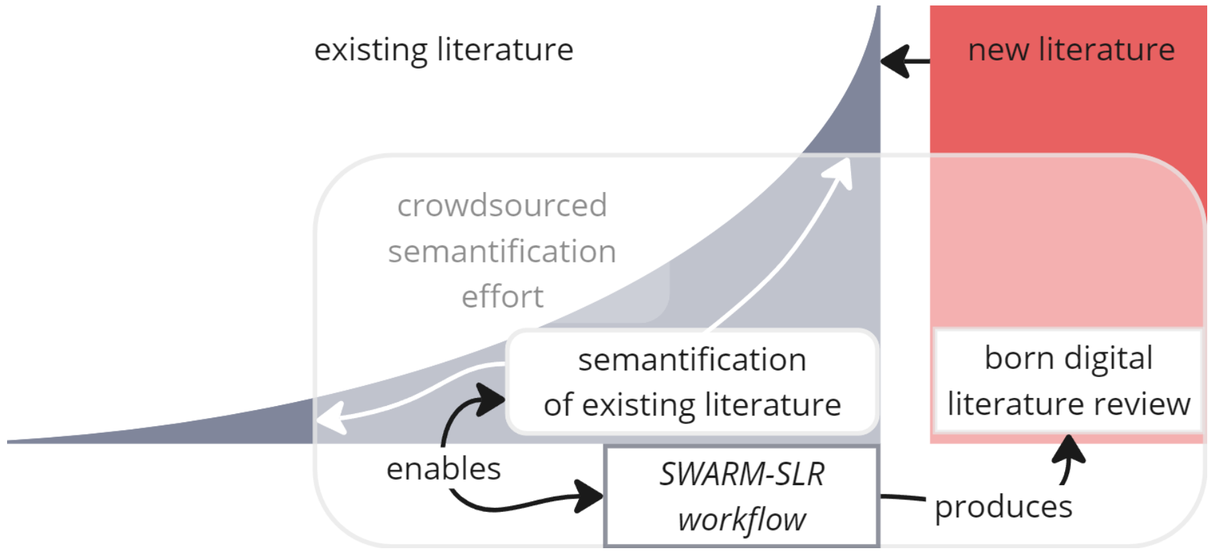

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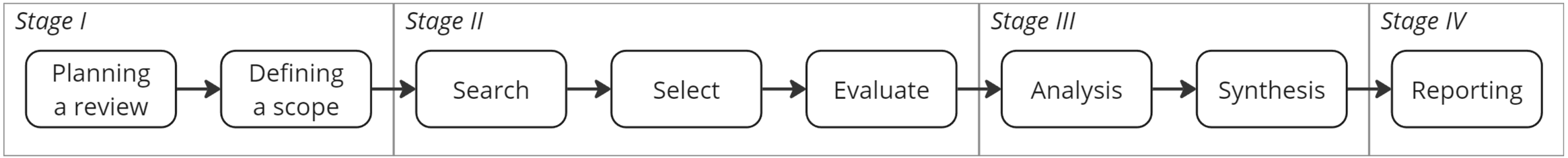
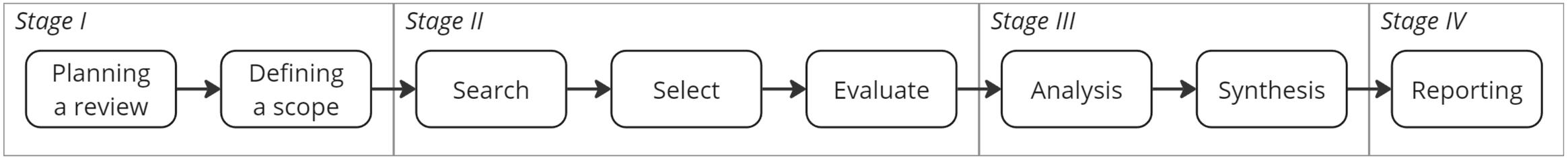
State of the Art



State of the Art: Everything can be supported



Mapping papers in relation to automation methods and SLR according to Pulsiri and Vatananan-Thesenvitz [1]

Stage	Task	Semi-automated	Fully automated
I	*Planning a review*	[50][34][49]	
	Defining a scope	[50][34][49]	
II	*Search*	[41][46][34]	[18][49][24]
	Select	[37][41][46][34][53][47][54]	[18][50][49]
	Evaluate	[46][34]	[18][50][49]
III	*Analysis*	[46][50][34][35][49]	
	Synthesis	[46][50][34][49]	
IV	*Reporting*	[46][50][34][49]	

[1] Pulsiri, N., Vatananan-Thesenvitz, R.: Improving Systematic Literature Review with Automation and Bibliometrics. In: 2018 Portland International Conference on Management of Engineering and Technology (PICMET). pp. 1–8 (2018). https://doi.org/10.23919/PICMET.2018.8481746, ISSN: 2159-5100

Specification: Task specific requirements

Table 2: SWARM-SLR requirements of stage I.

Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
1. Planning a review	*1. Formulate research interest*	explicit informal research interest	1	formalize abstract interest
			2	utilize central keywords
2. Defining a scope	*1. Check for related research questions*	narrowed informal research interest	3	know what previous scholarly works already covered
			4	know what previous scholarly works were missing
	2. Refine scientific interest	specific research question	5	use specific vocabulary
			6	state a clear scope
			7	state a clear perspective
	3. Formulate Search Query	preliminary weighted keywords and queries	8	use relevant keywords
			9	weight individual keywords
	4. Refine with related literature	weighted keywords and refined queries	10	extend the vocabulary
			11	identify polysemes and synonyms
	5. Reevaluate with domain experts	validated weighted keywords and queries	12	validate research questions
			13	validate keywords
			14	validate weights
			15	validate search query

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			14	validate weights
			15	validate search query

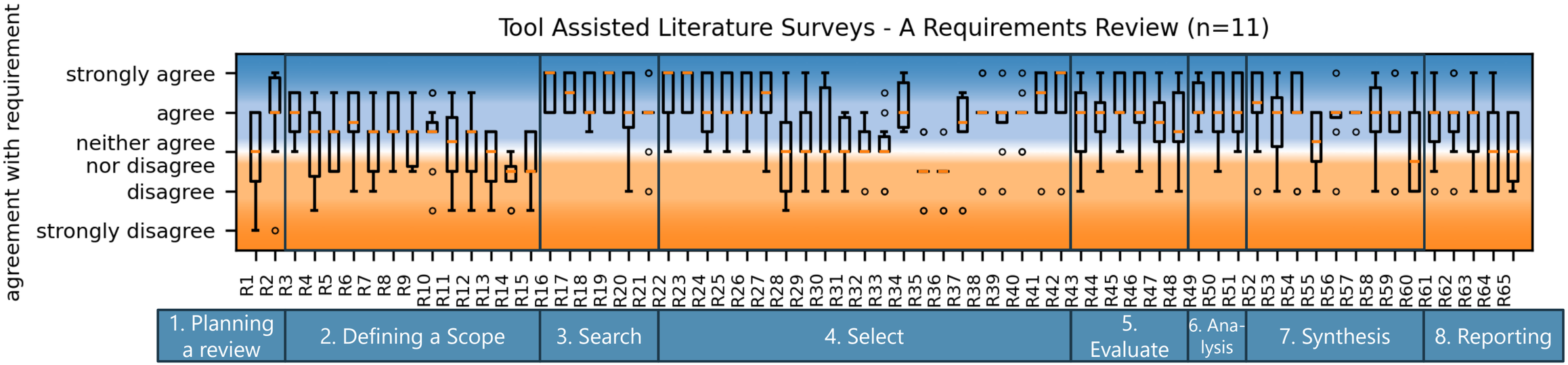
Table 3: SWARM-SLR requirements of stage II

Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
3. Search	*1. Find resources*	preliminary document set	16	use reliable sources
			17	find relevant documents
			18	find similar documents
	2. Remove duplicates and find missing documents	curated document set	19	identify duplicate documents
			20	find unindexed documents
			21	identify document set gaps
4. Select	*1. Extract structured data from documents*	metadata	22	extract publication date
			23	extract author(s)
			24	extract publication venue
			25	extract specified keywords
		content	26	extract document text
			27	differentiate chapters
		bag of words	28	remove special character
			29	identify multi-words
			30	expand acronyms
			31	lemmatize words
			32	normalize words
			33	remove stop words
		contribution statements	34	identify statements
	2. Calculate relational measurements within the document set	document representation	35	calculate "term frequency" (tf) and "term frequency - inverse document frequency" (tf-idf)
			36	calculate word embedding and document embedding
			37	represent document machine-readable
		similarity of documents within the document set	38	consider synonyms
			39	consider polysemes
			40	calculate document similarity
	3. Identify documents relevant for the research questions	relevance of documents for research question	41	represent research question machine-readable
			42	calculate document relevancy for research question
5. Eval -uate	*1. Remove out-of-scope document subset*	in-scope document set	43	define in-/exclusion criteria
			44	exclude documents
	2. Evaluate relevancy measurement	selection approval	45	evaluate similarity of documents
			46	evaluate relevance of documents
	3. Classify document subsets	literature subsets	47	calculate variables
			48	divide document set into subsets

Table 4: SWARM-SLR requirements of stage III and IV

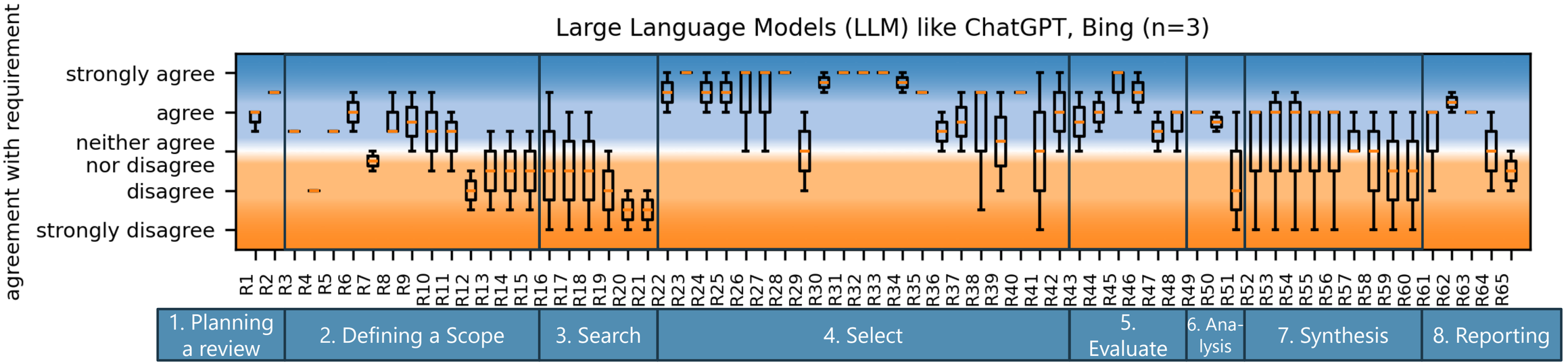
Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
6. Analysis	*1. Annotate resources*	contribution representation	49	annotate the document
			50	represent the annotation machine-readable
			51	annotate collaboratively
7. Synthesis	*1. Compare contributions*	comparison	52	define comparison properties
			53	insert contribution values
	2. Craft arguments based on findings	document claims	54	identify evidence (data)
			55	establish warrant
	3. Critique the literature	thesis claims	56	identify evidence (claims)
			57	identify patterns
			58	detect fallacies
			59	identify conflicts
			60	resolve conflicts
8. Reporting	*1. Write the literature review*	review article	61	utilize comparisons
			62	support claims
			63	establish outline
			64	draft iteration(s)
			65	audit iteration(s)

Evaluation: Requirements and Workflow



- Requirements largely confirmed
  - reserved skepticism towards a tool supporting *Step 2.5 Reevaluate with domain experts* (R12-R15)
- No missing requirements reported
- Survey ongoing and available online
  - Including responses, analysis code, visualizations, ...

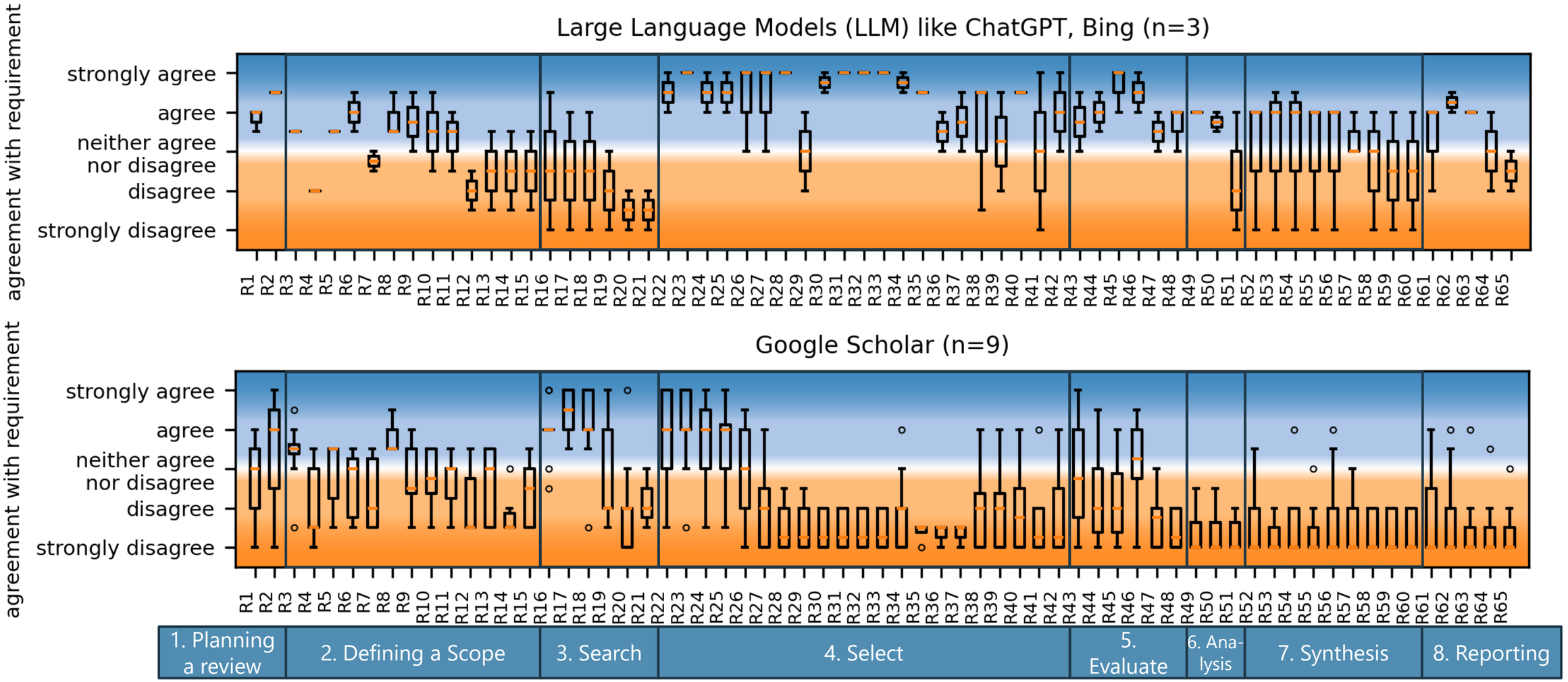
Tool evaluation: ChatGPT



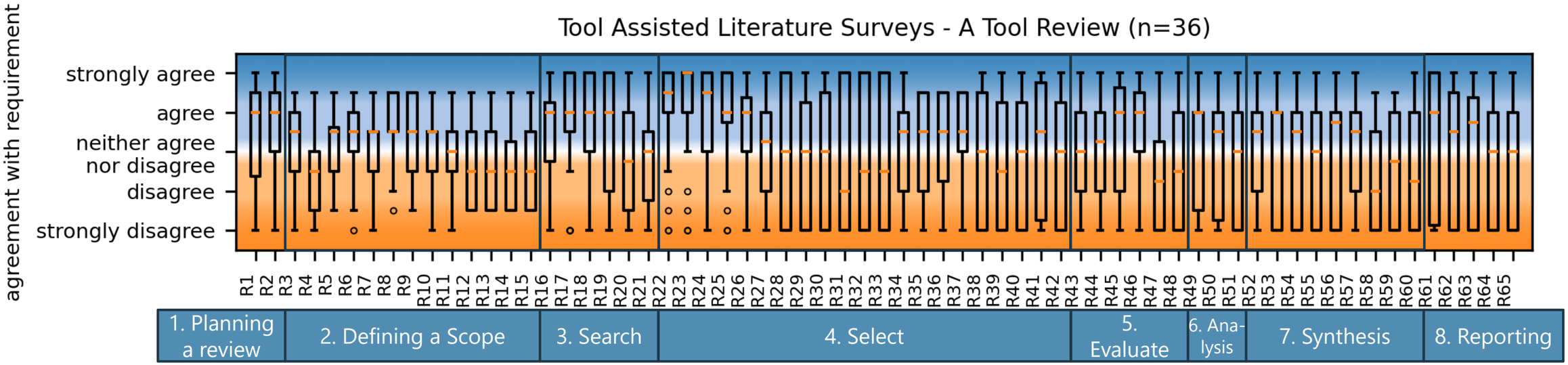
- Use requirements to measure task specific tool fitness

- E.g. LLM like ChatGPT:
  - Strong in ideation, text extraction, writing
  - Weak in reliability and verification

Tool evaluation: ChatGPT vs. Google Scholar



Evaluation: All tools



- Every requirement can be fulfilled by at least one tool
- No tool meets all requirements alone

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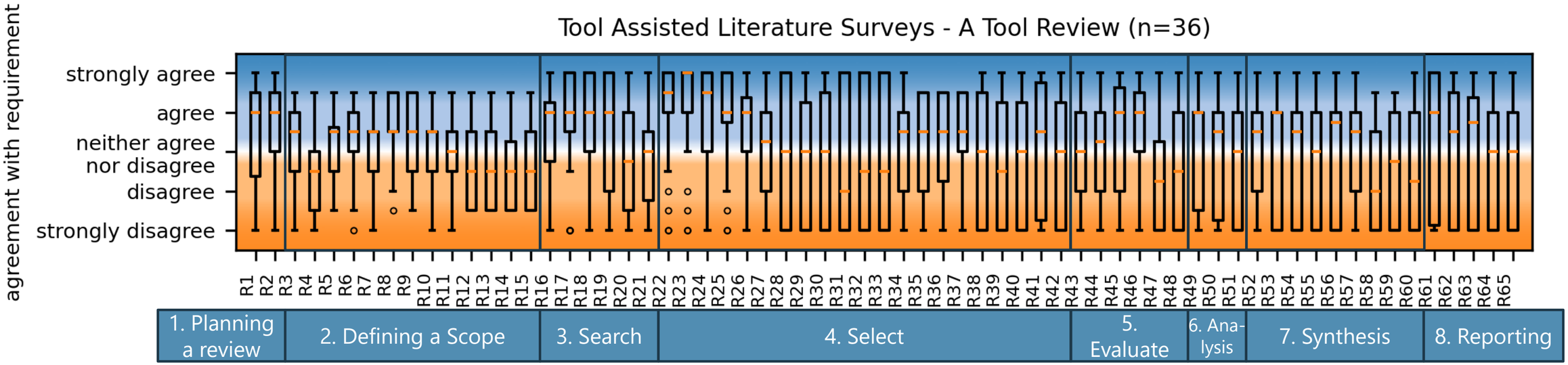
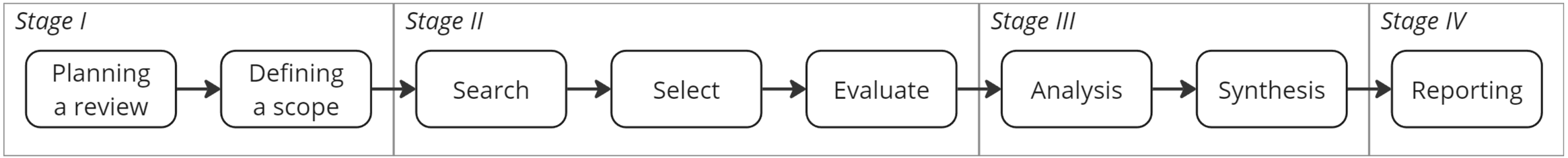


- Every requirement can be fulfilled by at least one tool
- No tool meets all requirements alone
- **Next step:** Chain the best fitted tools together!

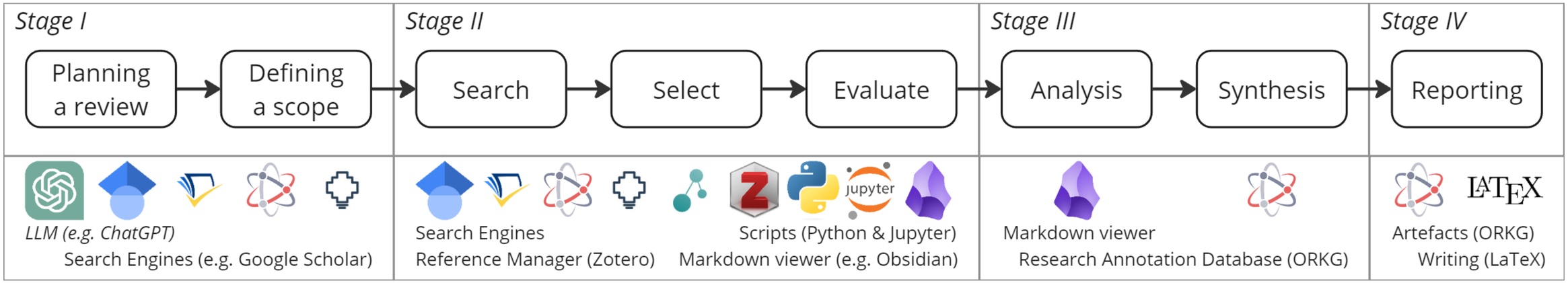
Unified Workflow



Goals:

- Build a modular, streamlined workflow
- Fullfill all requirements with the „best“ tool available
  - easy to use, large community, accessible for free, interoperable, …
- Workflow should be automated where possible, semi-automated human-in-the-loop where needed.

Unified Workflow: 4 Jupyter Notebooks



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Demonstration

tools/scripts/SWARM-SLR/SWA

github.com/borgnetzwerk/tools/blob/main/scripts/SWARM-SLR/SWAR...

Files | main | tools / scripts / SWARM-SLR / SWARM-SLR_Stage_I.ipynb | Top

Preview | Code | Blame | Raw

In [ ]:

```
Given the following research interest:
"I want to understand what engineers use to describe their knowledge. I know they use CPACS

Provide a list of relevant keywords from the given research interest. Provide the list with
Then provide a list of 10 additional relevant scientific keywords for this research interest
Then formalize this research interest using these scientific keywords. Highlight the keyworc

Provide the entire answer as one code block.
```

Output / Result (LLM Reply)

Keywords from Given Research Interest:

- CPACS

SWARM-SLR Workflow (online)

chatgpt.com

ChatGPT Auto

LLM

Erstelle ein Bild für meine Präsentation

Vokabeln lernen

Sende eine Nachricht an ChatGPT

ChatGPT kann Fehler machen. Überprüfe wichtige Informationen.

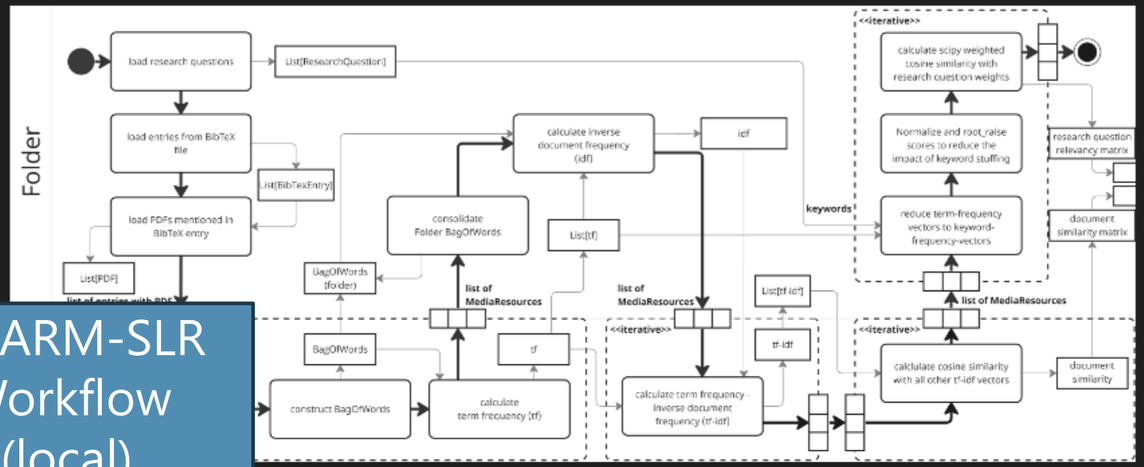
tools

SWARM-SLR_Stage_II.ipynb | SWARM-SLR_Stage_III.ipynb | SWARM-SLR_Stage_IV.ipynb

scripts > SWARM-SLR > SWARM-SLR_Stage_II.ipynb > Stage II > Task 4: Select > # Task 4: Select

+ Code | + Markdown | Run All | Clear All Outputs | Outline | Select Kernel

Since this task is done largely computationally, the following graphic adds insight into each step and their interaction.

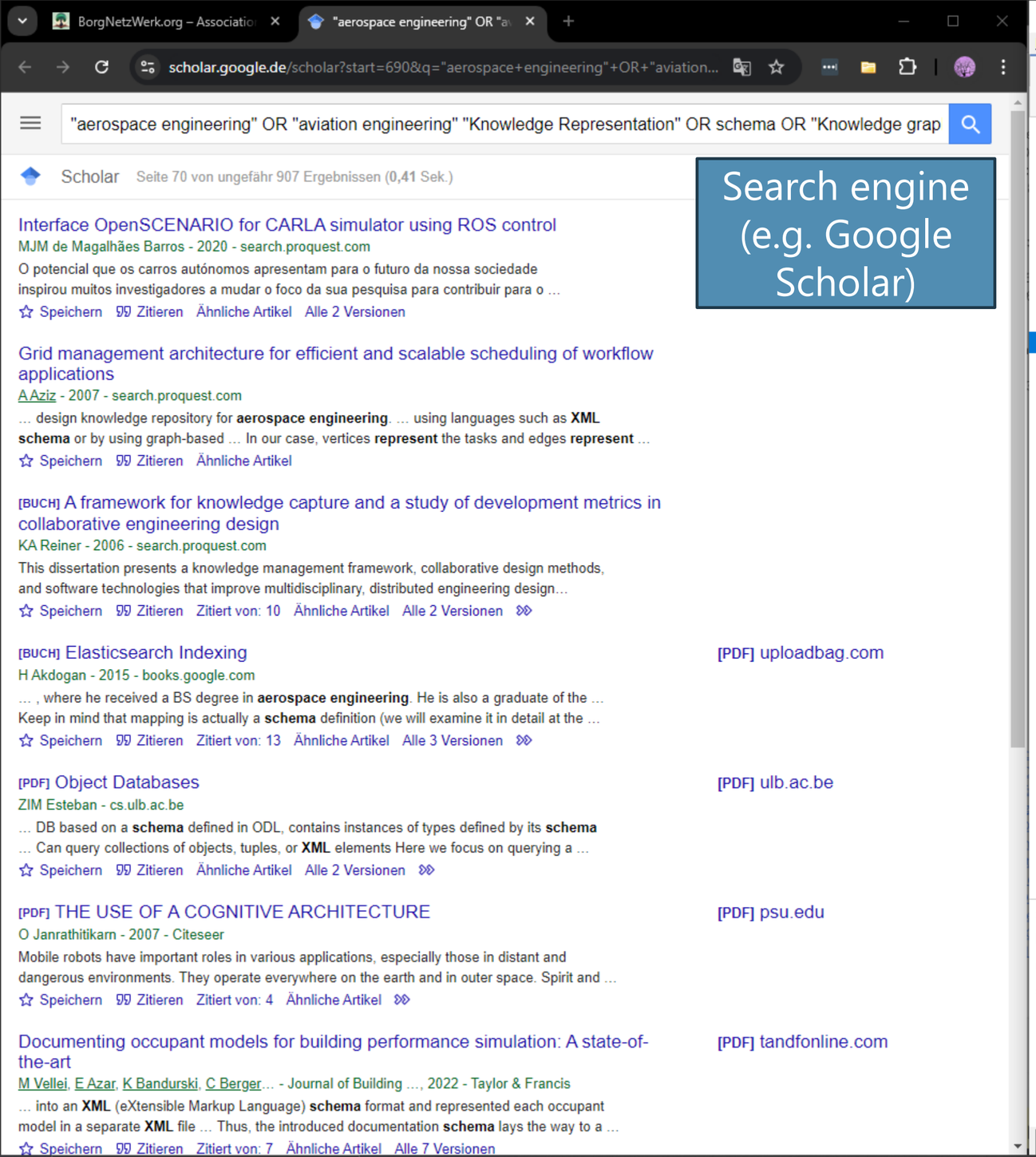


SWARM-SLR Workflow (local)

```python
# Task 4: Select
# Setup
from bnw_tools.extract.nlp import util_nlp
from bnw_tools.publish import util_wordcloud
from bnw_tools.publish.Obsidian import nlped_whispered_folder

folder_path = "D:/workspace/Zotero/SE2A-B4-2"
language = "en"
nlptools = util_nlp.NLPTools()

# Analyze Step (4.1, 4.2 und 4.3)
folder = util_nlp.Folder(folder_path, nlptools=nlptools, language=language)

# Publish (for better usability)
util_wordcloud.folder(folder)
nlped_whispered_folder.folder(folder, force=True)
```

Python

main | Spaces: 4 | Cell 10 of 34 | 8 Spell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Scholar
Seite 70 von ungefähr 907 Ergebnissen (0,41 Sek.)
Search engine (e.g. Google Scholar)
Interface OpenSCENARIO for CARLA simulator using ROS control
MJM de Magalhães Barros - 2020 - search.proquest.com
O potencial que os carros autónomos apresentam para o futuro da nossa sociedade inspirou muitos investigadores a mudar o foco da sua pesquisa para contribuir para o ...
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... design knowledge repository for aerospace engineering. ... using languages such as XML schema or by using graph-based ... In our case, vertices represent the tasks and edges represent ...
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[BUCH] Elasticsearch Indexing
[PDF] uploadbag.com
H Akdogan - 2015 - books.google.com
... , where he received a BS degree in aerospace engineering. He is also a graduate of the ... Keep in mind that mapping is actually a schema definition (we will examine it in detail at the ...
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[PDF] Object Databases
[PDF] ulb.ac.be
ZIM Esteban - cs.ulb.ac.be
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Documenting occupant models for building performance simulation: A state-of-the-art
[PDF] tandfonline.com
M Vellei, E Azar, K Bandurski, C Berger... - Journal of Building ..., 2022 - Taylor & Francis
... into an XML (eXtensible Markup Language) schema format and represented each occupant model in a separate XML file ... Thus, the introduced documentation schema lays the way to a ...
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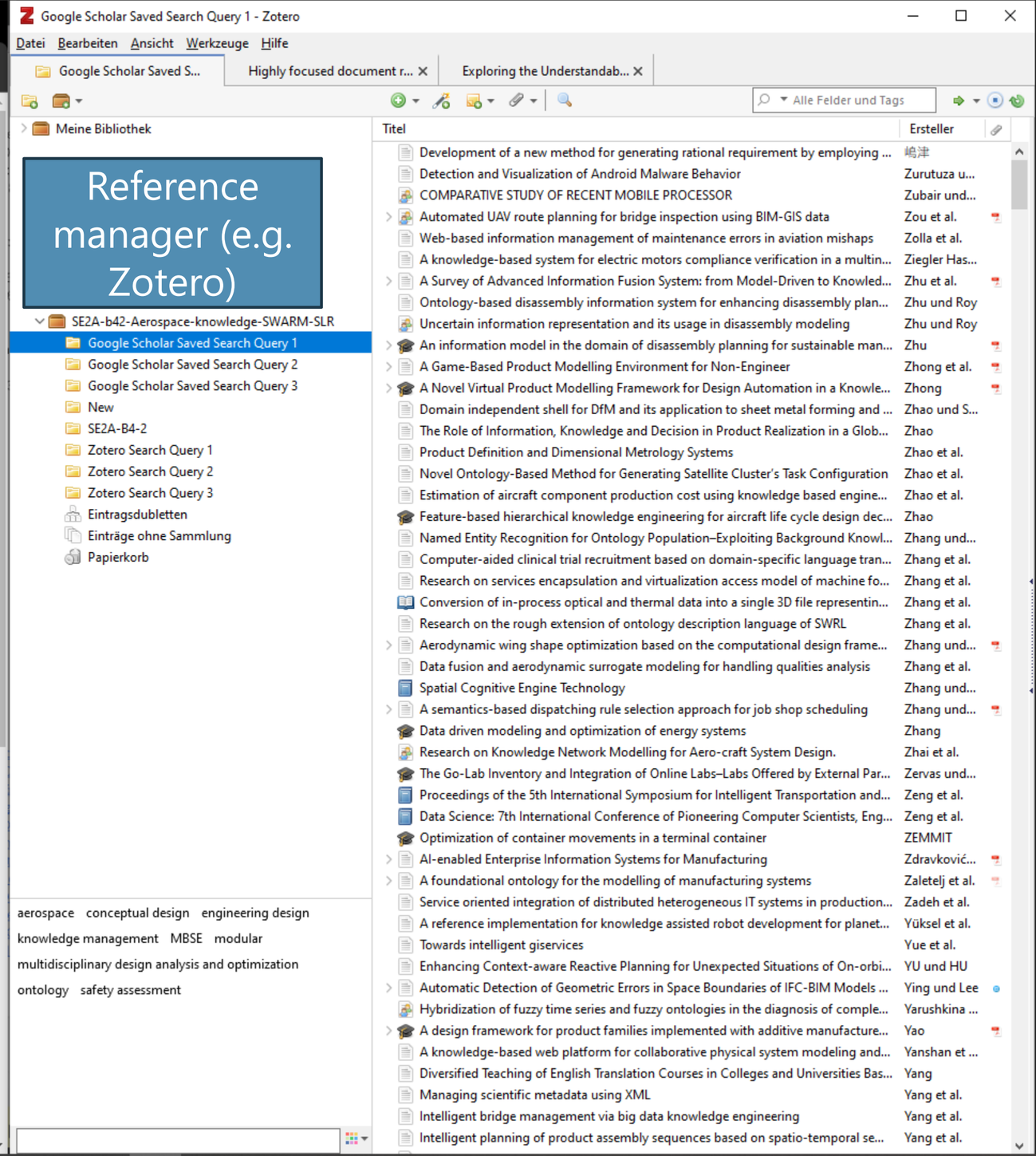
Google Scholar Saved Search Query 1 - Zotero
Datei Bearbeiten Ansicht Werkzeuge Hilfe
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Highly focused document r...
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Reference manager (e.g. Zotero)
Meine Bibliothek
SE2A-b42-Aerospace-knowledge-SWARM-SLR
Google Scholar Saved Search Query 1
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Google Scholar Saved Search Query 3
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SE2A-B4-2
Zotero Search Query 1
Zotero Search Query 2
Zotero Search Query 3
Eintragsdubletten
Einträge ohne Sammlung
Papierkorb
aerospace conceptual design engineering design
knowledge management MBSE modular
multidisciplinary design analysis and optimization
ontology safety assessment
Titel
Ersteller
Development of a new method for generating rational requirement by employing ... 屿津
Detection and Visualization of Android Malware Behavior Zurutuza u...
COMPARATIVE STUDY OF RECENT MOBILE PROCESSOR Zubair und...
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Web-based information management of maintenance errors in aviation mishaps Zolla et al.
A knowledge-based system for electric motors compliance verification in a multin... Ziegler Has...
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An information model in the domain of disassembly planning for sustainable man... Zhu
A Game-Based Product Modelling Environment for Non-Engineer Zhong et al.
A Novel Virtual Product Modelling Framework for Design Automation in a Knowle... Zhong
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Product Definition and Dimensional Metrology Systems Zhao et al.
Novel Ontology-Based Method for Generating Satellite Cluster's Task Configuration Zhao et al.
Estimation of aircraft component production cost using knowledge based engine... Zhao et al.
Feature-based hierarchical knowledge engineering for aircraft life cycle design dec... Zhao
Named Entity Recognition for Ontology Population–Exploiting Background Knowl... Zhang und...
Computer-aided clinical trial recruitment based on domain-specific language tran... Zhang et al.
Research on services encapsulation and virtualization access model of machine fo... Zhang et al.
Conversion of in-process optical and thermal data into a single 3D file representin... Zhang et al.
Research on the rough extension of ontology description language of SWRL Zhang et al.
Aerodynamic wing shape optimization based on the computational design frame... Zhang und...
Data fusion and aerodynamic surrogate modeling for handling qualities analysis Zhang et al.
Spatial Cognitive Engine Technology Zhang und...
A semantics-based dispatching rule selection approach for job shop scheduling Zhang und...
Data driven modeling and optimization of energy systems Zhang
Research on Knowledge Network Modelling for Aero-craft System Design. Zhai et al.
The Go-Lab Inventory and Integration of Online Labs–Labs Offered by External Par... Zervas und...
Proceedings of the 5th International Symposium for Intelligent Transportation and... Zeng et al.
Data Science: 7th International Conference of Pioneering Computer Scientists, Eng... Zeng et al.
Optimization of container movements in a terminal container ZEMMIT
AI-enabled Enterprise Information Systems for Manufacturing Zdravković...
A foundational ontology for the modelling of manufacturing systems Zaletelj et al.
Service oriented integration of distributed heterogeneous IT systems in production... Zadeh et al.
A reference implementation for knowledge assisted robot development for planet... Yüksel et al.
Towards intelligent giservices Yue et al.
Enhancing Context-aware Reactive Planning for Unexpected Situations of On-orbi... YU und HU
Automatic Detection of Geometric Errors in Space Boundaries of IFC-BIM Models ... Ying und Lee
Hybridization of fuzzy time series and fuzzy ontologies in the diagnosis of comple... Yarushkina ...
A design framework for product families implemented with additive manufacture... Yao
A knowledge-based web platform for collaborative physical system modeling and... Yanshan et ...
Diversified Teaching of English Translation Courses in Colleges and Universities Bas... Yang
Managing scientific metadata using XML Yang et al.
Intelligent bridge management via big data knowledge engineering Yang et al.
Intelligent planning of product assembly sequences based on spatio-temporal se... Yang et al.

Miro

Boards | SWARM-SLR - Miro | SLR Progress - Miro | SLR Workshop - Miro | SLR Results - Miro

miro | SLR Progress

Present | Share

Noteboard (e.g. Miro)

Copy of Keywords

Keywords

Frame 1

Frame 2

Frame 3

Frame 4

11%

RQ1

00_RQs / RQ1

Markdown viewer (e.g. Obsidian)

RQ1

Keywords

aerospace engineering

aerospace engineer:: 10
aerospace engineering:: 10
airspace engineer:: 10
airspace engineering:: 10
airplane engineer:: 10
airplane engineering:: 10
aironautic engineer:: 10
aironautic engineering:: 10
aircraft engineer:: 10
aircraft engineering:: 10
spacecraft engineer:: 10
spacecraft engineering:: 10
avionics engineer:: 10
avionics engineering:: 10
aviation engineer:: 10
aviation engineering:: 10

knowledge representation

knowledge representation:: 10
Knowledge graph:: 10
Ontology:: 10
information representation:: 8
Taxonomy:: 8
Semantic Web:: 8
knowledge engineering:: 7
schema:: 7
expert system:: 6

Task 5 Eva... | Task 6 An... | Task 7.1 S...

00_RQs / Task 5 Evaluate

Task 5 Evaluate

Research Questions

File (4)	RQ
RQ1	By which means, such as knowledge representations and schemas, do aerospace engineers externalize, such as formalize and visualize, knowledge?
RQ2	By which means, such as knowledge bases and services, do aerospace engineers utilize, such as organize and interface with, explicit knowledge?
RQ3	By which means, such as tools and methods, do aerospace engineers exchange, such as transfer and distribute, explicit knowledge?
RQ4	aerospace engineering

Next best candidates

G... | Total | Com... | Task 6 Fi... | concepts | Notes

Graph view

Filters

Search files...

Tags

Attachments

Existing files only

Orphans

Groups

/review_score:: 5/

/review_score:: 4/

/review_score:: 3/

/review_score:: 2/

/review_score:: 1/

Stage I

In this stage, we transition from an implicit informal research interest to a set of formalized human- and machine-readable research questions.

Workload distribution

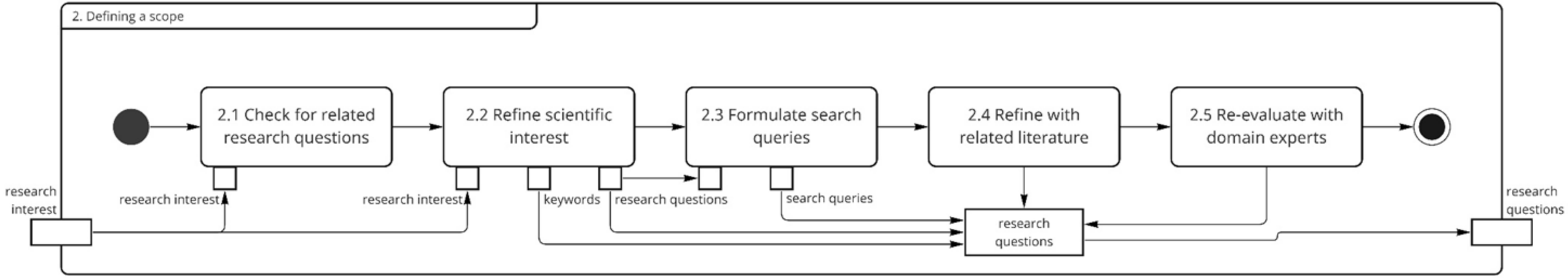
Actor	Time
Researcher	300 min
Machine	15 min
Domain Experts	10 min

Tools

- LLM (e.g. ChatGPT)
- Search Engine / Database Interface (e.g. Google Scholar, Semantic Scholar, ORKG and OKMaps)
- Optional:
  - Markdown file viewer (e.g. Obsidian, preferably with Dataview plugin)

Task 1: Planning a review

Stage I: Use LLM at their best



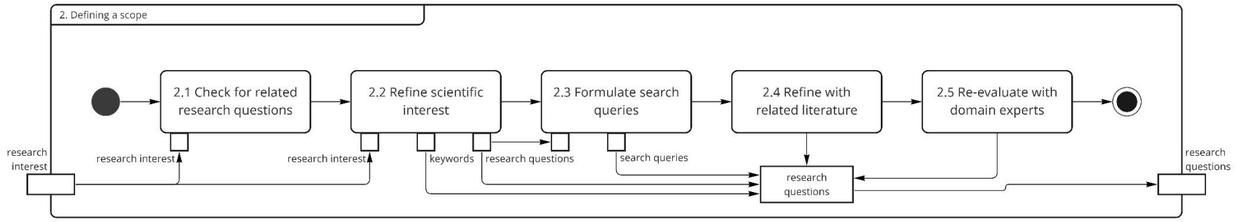
- Formulate
  - Research questions
  - Keywords
  - Search queries

- **BUT:** Validate with human expertes as well

Stage I: Use LLM at their best

Task 2: Defining a scope

Step	Result	Requirement
Check for related research questions	narrowed informal research interest	3. know what previous scholarly works already covered 4. know what previous scholarly works were missing
Refine scientific interest	specific research question	5. use specific vocabulary 6. state a clear scope 7. state a clear perspective
Formulate Search Query	preliminary weighted keywords and queries	8. use relevant keywords 9. weight individual keywords
Refine with related literature	weighted keywords and refined queries	10. extend the vocabulary 11. identify polysemes and synonyms
Re-evaluate with domain experts	validated weighted keywords and queries	12. validate research questions 13. validate keywords 14. validate weights 15. validate search query



Step 2.1: Check for related research questions

Requirements:

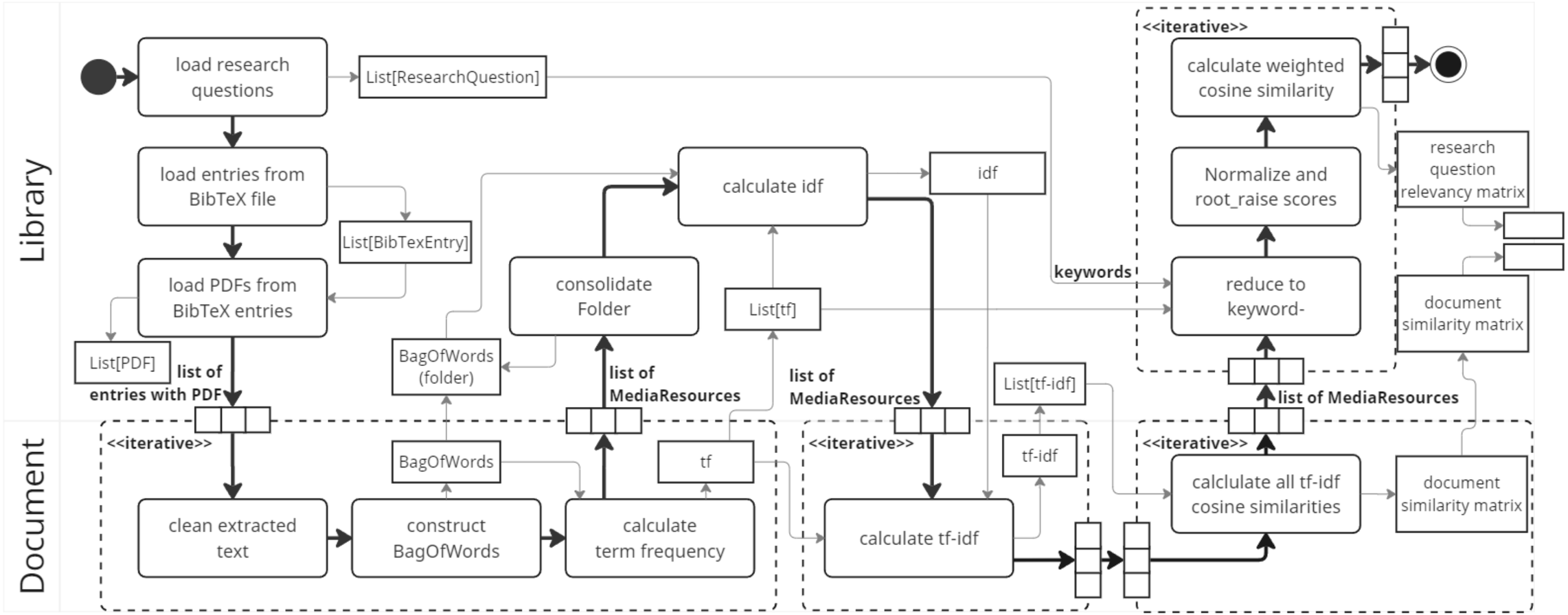
- Know what previous scholarly works already covered
- Know what previous scholarly works were missing

To achieve this, we query large databases, such as Google Scholar and Semantic Scholar, as well as more tailored solutions like the ORKG and OKMaps. While the general approach stays the same (Search -> Find -> Open -> Read document), there are differences when using each solution:

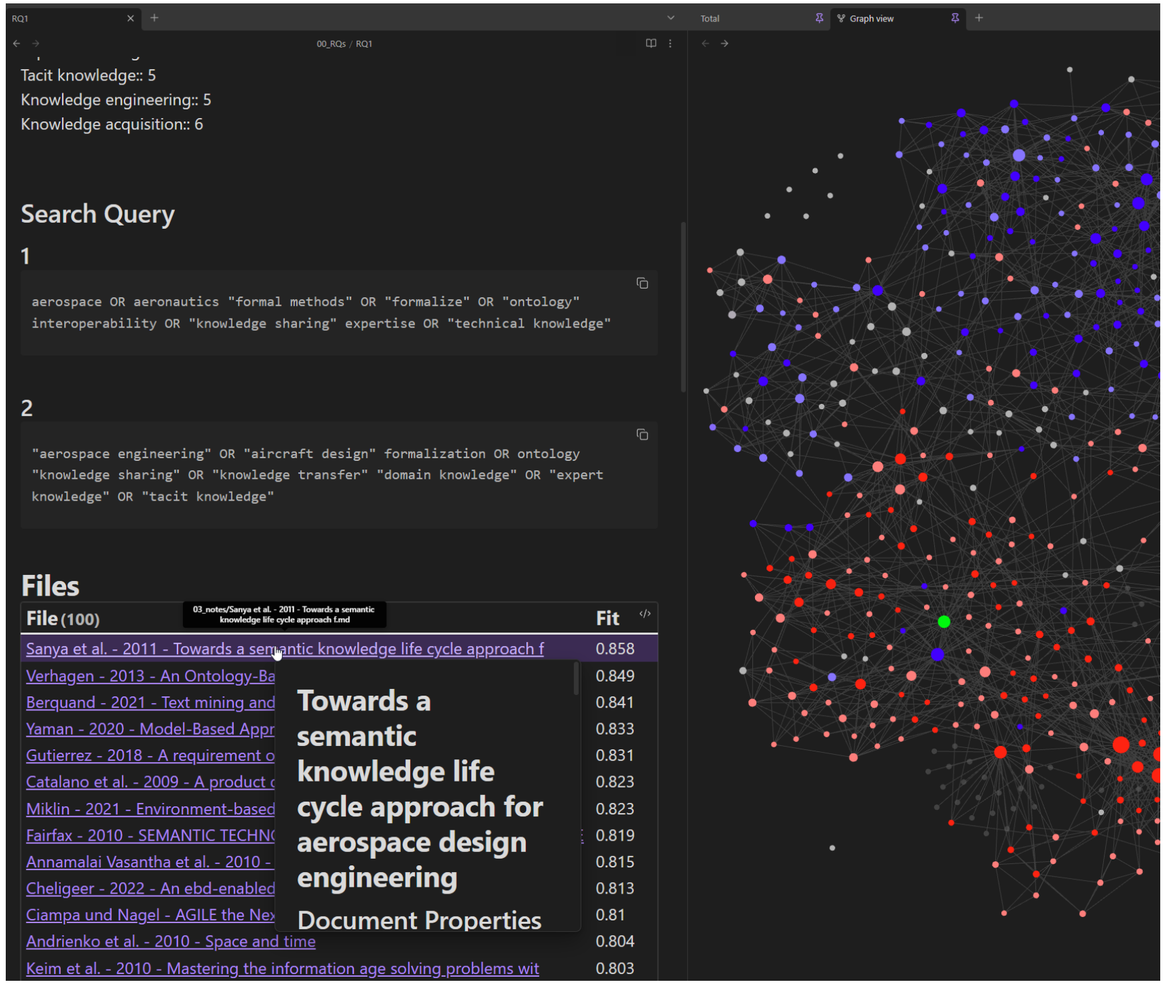
- **Google Scholar**
  - Many operators for querying https://scholar.google.de/ are deprecated, only `A -B`, `A OR B` and `"A B"`, as well as `author:A` and `source:B` still work. It is best to use https://scholar.google.de/schhp?#d=gs_asd to get a feeling for how it's best queried. The most important are the following two:
  - `"knowledge work"` searches for the exact word group and ignores instances such as "work requires specific knowledge".
  - `knowledge OR work` searches for works which include either word.
    Note that `OR` links the objects (word or word group) left and right, making these identical:
    - `"knowledge work" OR Curation wiki`
    - `Curation OR "knowledge work" wiki`
- **Semantic Scholar**
  - Available under https://www.semanticscholar.org/, one queries Semantic Scholar similar to Google Scholar, just with a different advanced search syntax. Semantic Scholar is more focused on API access, leading to inventions of tools like the next one.
- **Open Knowledge Maps (OKMaps)**
  - https://openknowledgemaps.org/ uses the Semantic Scholar API to create "Knowledge Maps", which present up to 100 Documents most relevant to a given topic, clustered by their overarching topics. The user queries it the same way as Semantic Scholar, with a list of keywords in no particular syntax.
- **Open Research Knowledge Graph (ORKG)**
  - https://orkg.org/ can be directly queried for related research fields and questions:
    - https://orkg.org/search/knowledge?types=ResearchField,Problem
  - Additional types such as Paper, List, Comparison and Review are also recommendable, once explicitly formalized research questions are evaluated.

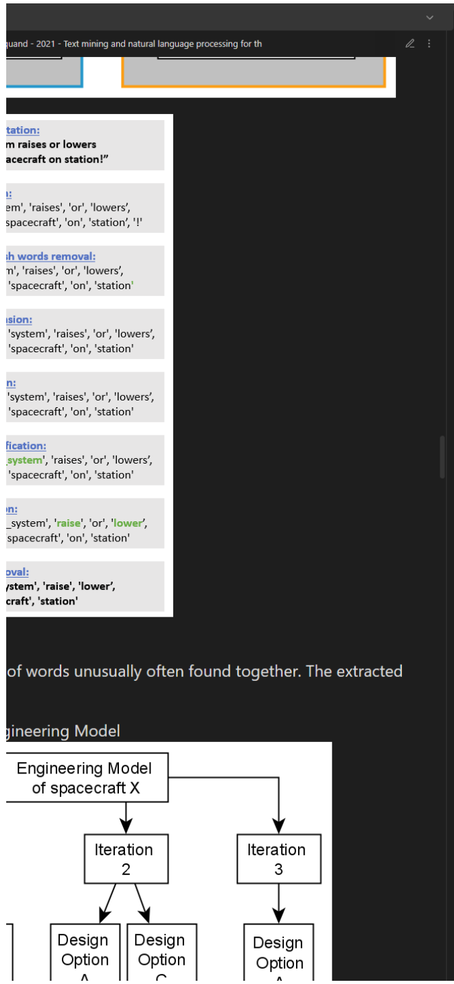
Stage II: Search, select and evaluate „fully automated“

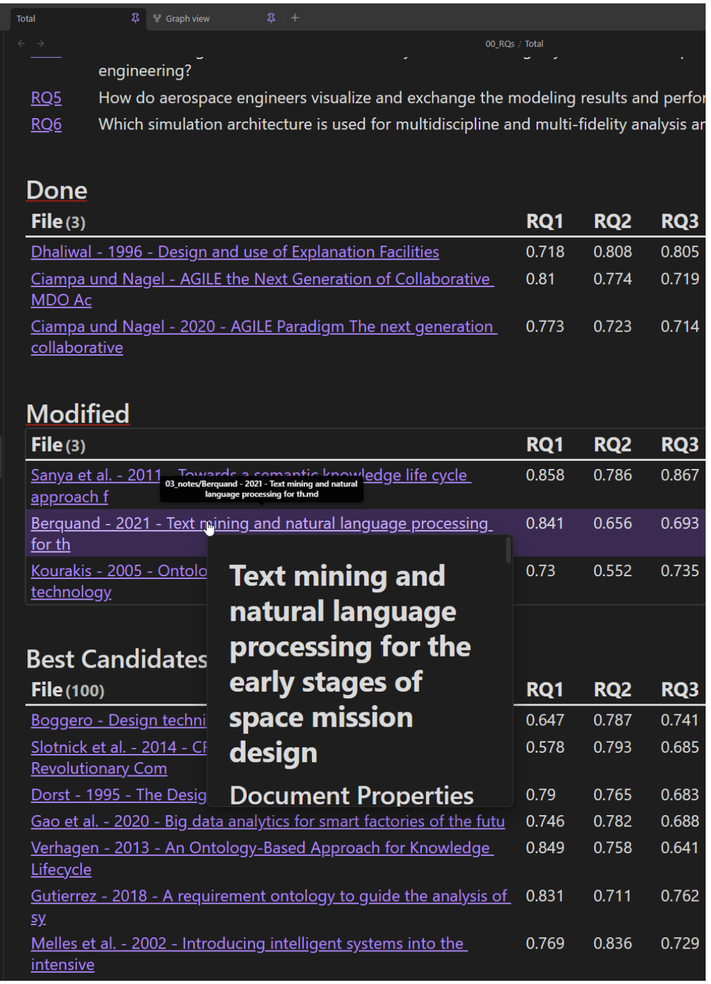
BUT: Human evaluation still required.



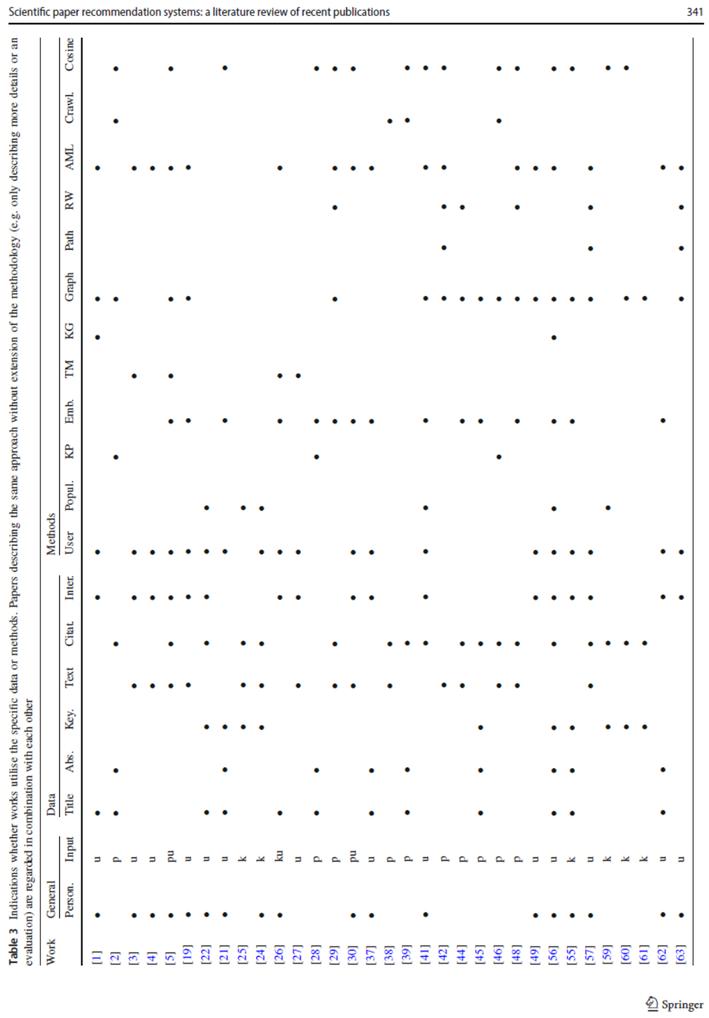
Stage III: Synthesis & Analysis: Don’t reinvent the wheel, use it.







Stage IV: Reporting: machine-actionable reviews

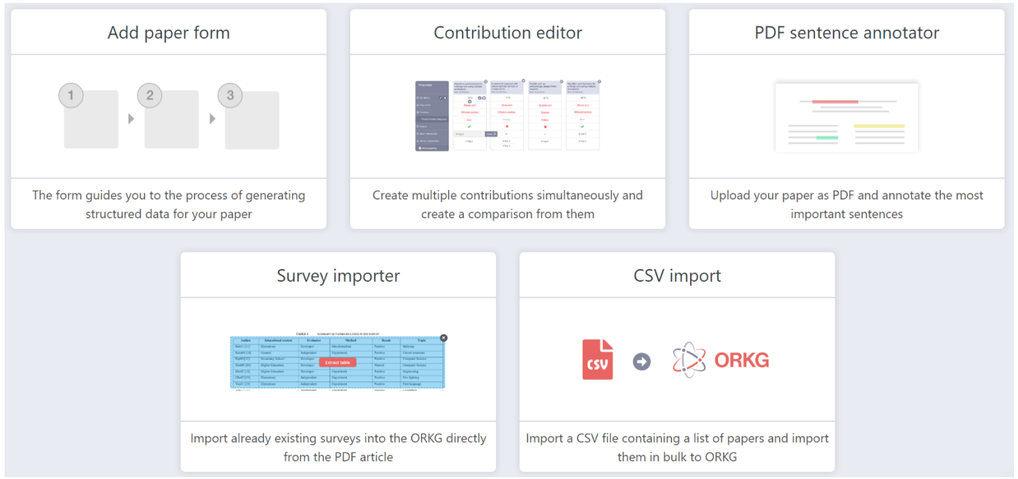


Scientific paper recommendation systems: a literature review of recent publications 341

Table 3 Indications whether works utilise the specific data or methods. Papers describing the same approach without extension of the methodology (e.g. only describing more details or an evaluation) are regarded in combination with each other

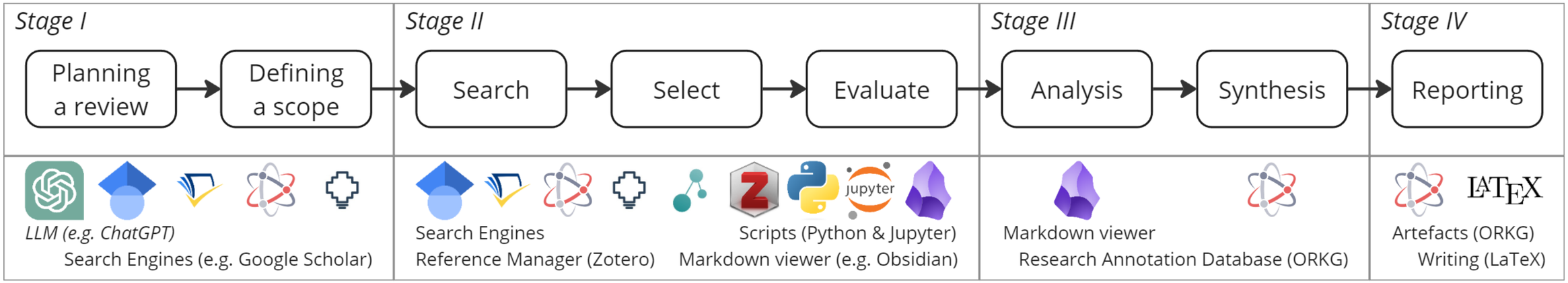
Work	General		Data						Methods																
	Person.	Input	Title	Abs.	Key.	Text	Citat.	Inter.	User	Popul.	KP	Emb.	TM	KG	Graph	Path	RW	AML	Crawl	Cosine
[1]	•	u	•																	
[2]		p	•	•			•				•									
[3]	•	u				•		•	•											
[4]		u				•			•											
[5]	•	pu				•	•	•	•									•		
[19]	•	u							•			•								
[22]	•	u							•			•								
[21]	•	u	•	•			•		•	•										
[25]		k			•															
[24]		k			•	•	•		•	•										
[26]		ka										•								
[27]		u				•		•	•				•							
[28]		p	•									•								
[29]	•	p				•					•	•			•					•
[30]		pu							•			•								•
[37]		u	•	•			•		•			•			•					•
[38]		p				•														
[39]		p					•	•												
[41]		u	•	•			•		•	•					•			•		•
[42]		p				•						•			•		•	•		•
[44]		p				•	•					•			•					•
[45]		p		•	•															
[46]		p				•	•					•			•					•
[48]		p				•	•													
[49]		u					•					•			•					•
[56]	•	u	•	•			•		•	•		•			•					•
[55]		k			•															
[57]	•	u	•	•		•	•		•	•		•			•			•		•
[59]		k			•															
[60]		k			•		•													
[61]		k			•		•													
[62]	•	u							•			•								•
[63]	•	u	•	•					•			•								•

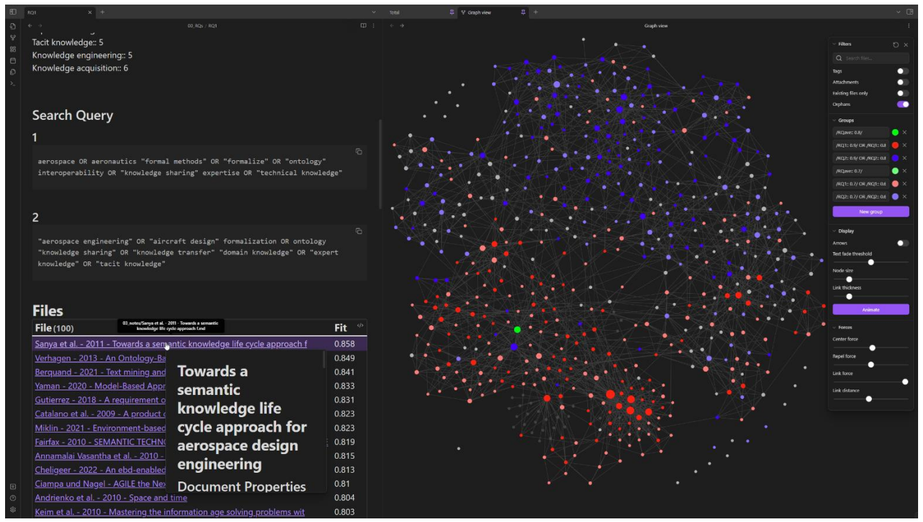
Springer

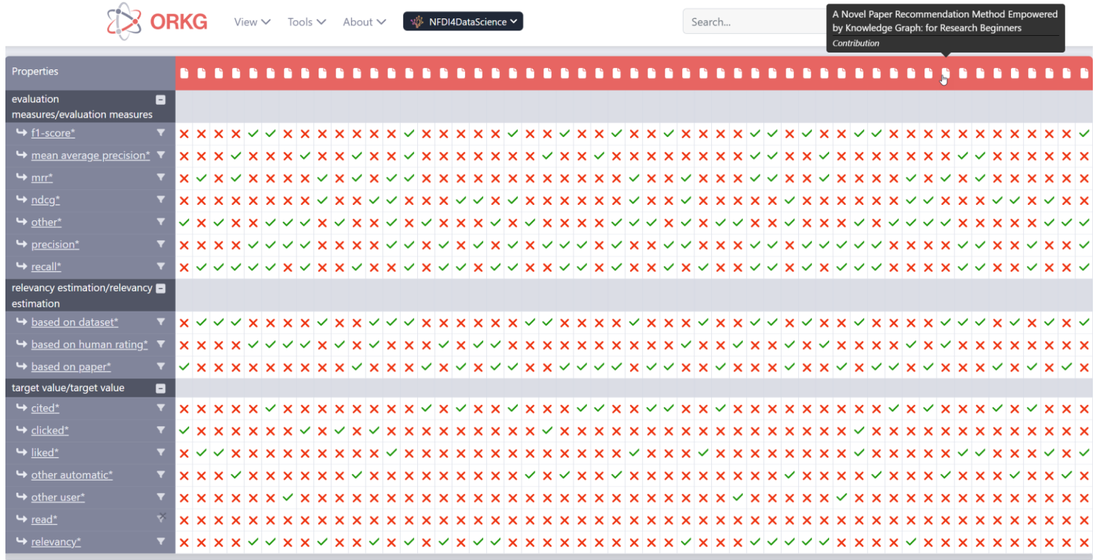


[1] Kreutz, C.K., Schenkel, R.: Scientific paper recommendation systems: a literature review of recent publications. International Journal on Digital Libraries 23(4), 335–369 (Dec 2022). https://doi.org/10.1007/s00799-022-00339-w

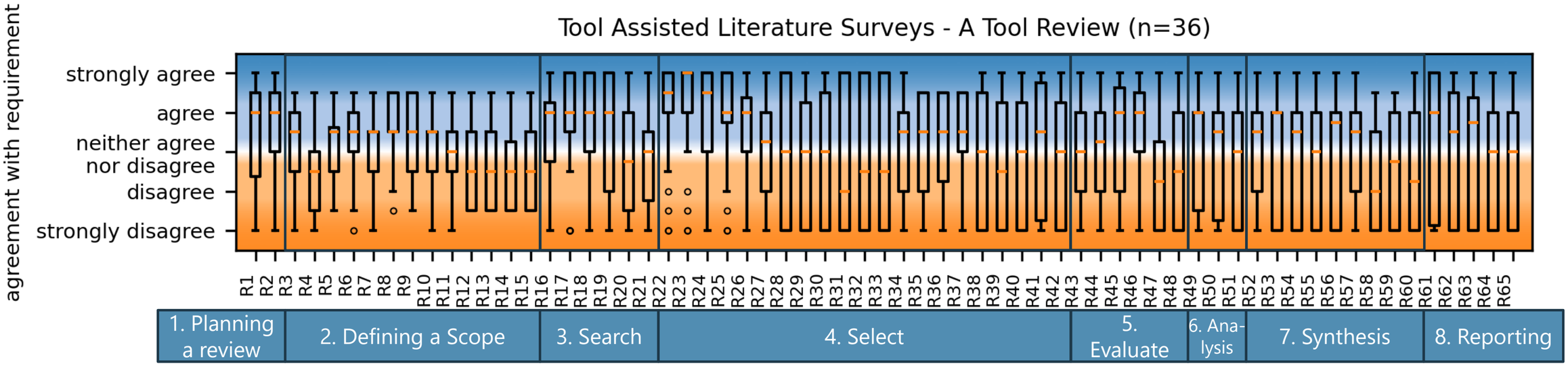
Workflow: From a question to a complete Review







Evaluation: All tools and the SWARM-SLR Workflow



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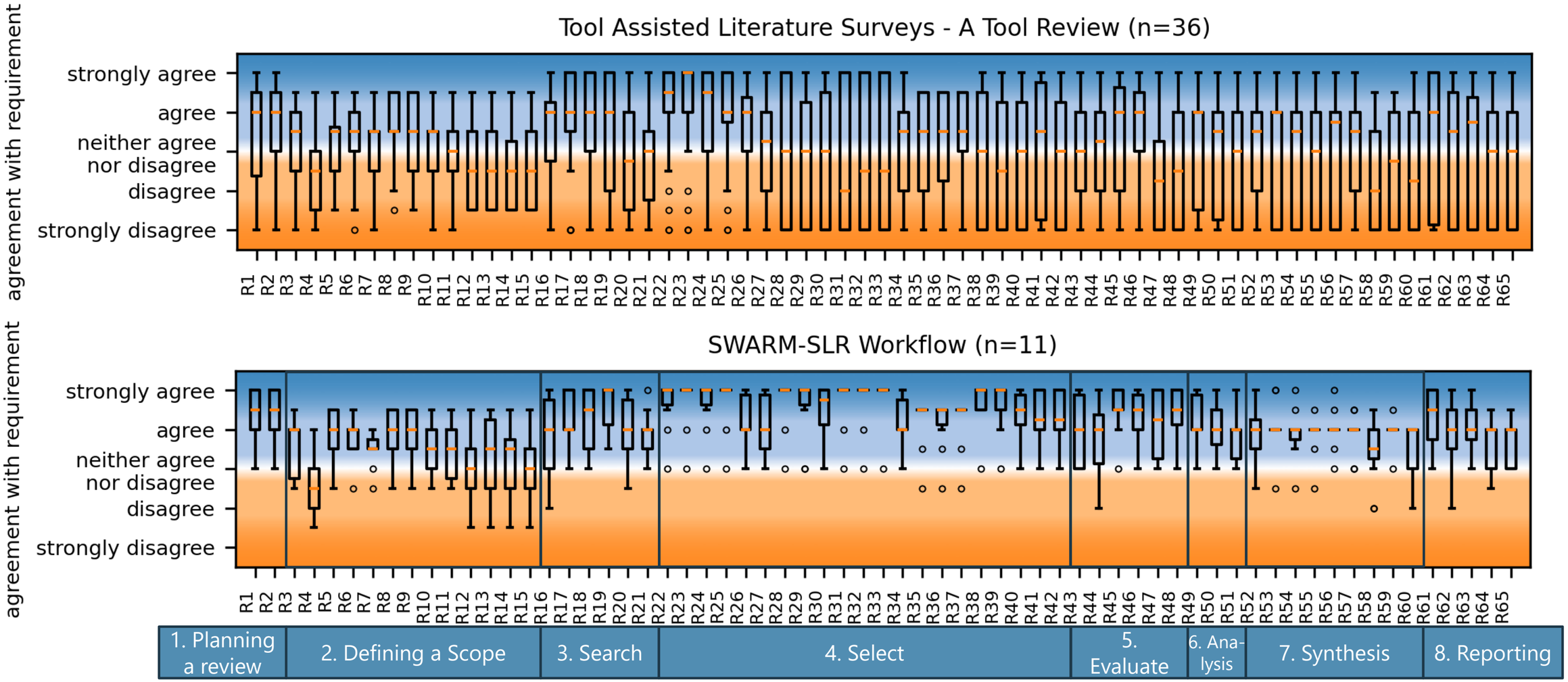
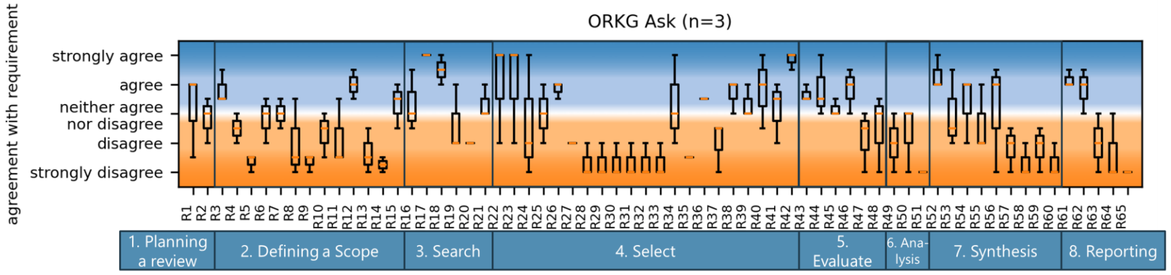


Future work: update, update, update

- During the writing of this, …
  - The „Systematic Literature Review Toolbox“ went offline since March 2024 [1]
  - ORKG Ask was released on April 2024 [2]
  - More tools will be developed, more requirements raised



[1] https://web.archive.org/web/20240000000000*/https://www.systematicreviewtools.com/
[2] https://ask.orkg.org/

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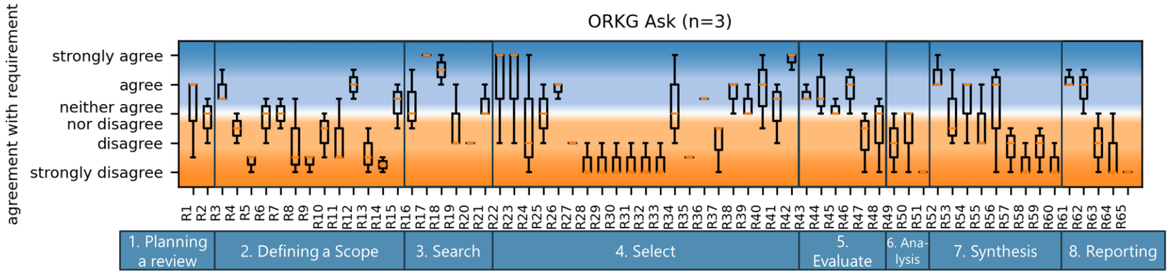
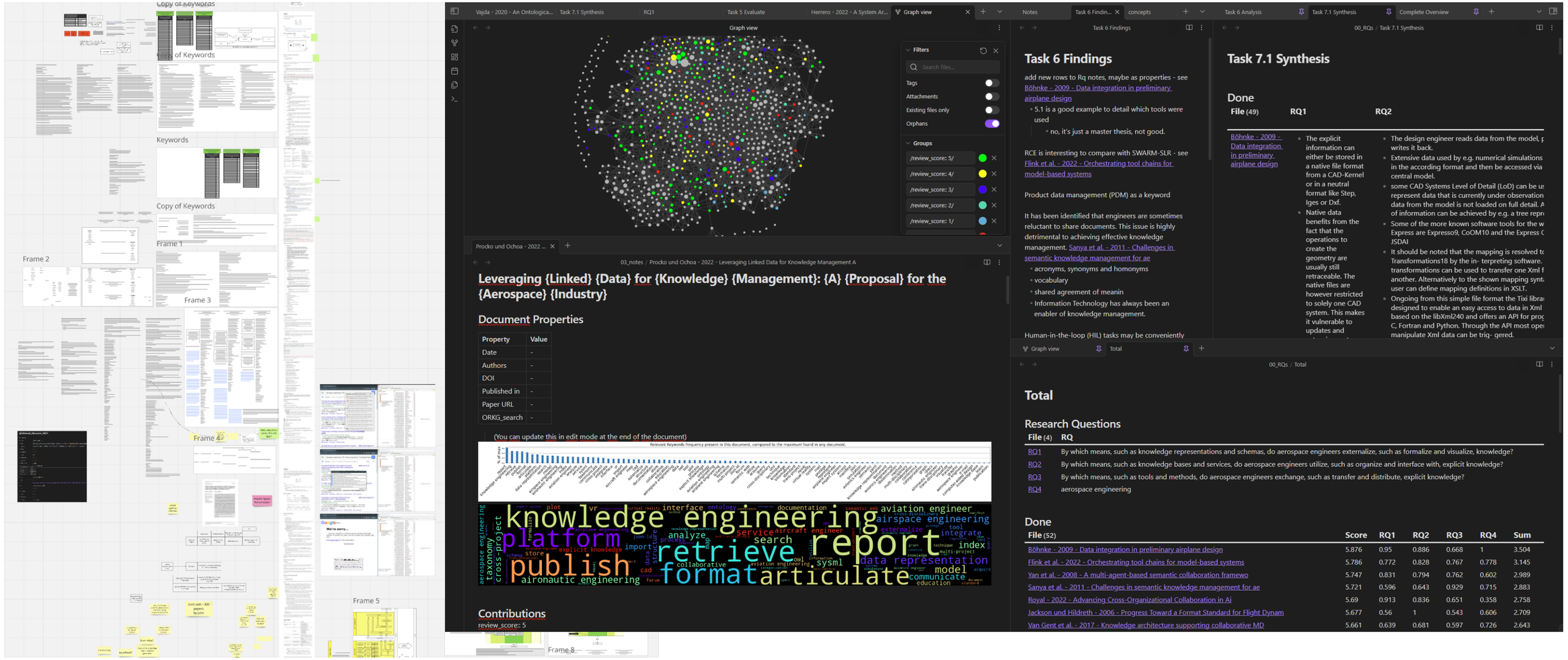


- We need more …
  - Requirement evaluation and detail differenciation [3]
  - Tool assessments and suggestions [3]
  - Workflow eveluation and updates [3]
  - Field testing and user feedback [3]

[3]

[1] https://web.archive.org/web/20240000000000*/https://www.systematicreviewtools.com/
[2] https://ask.orkg.org/

Future work: Using SWARM-SLR to conduct real SLR



Conclusion: Collaborate, coordinate, and conquer the literature flood

65 Requirements specified

Table 2: SWARM-SLR requirements of stage I.

Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
1. Planning a review	*1. Formulate research interest*	explicit informal research interest	1	formalize abstract interest
			2	utilize central keywords
2. Defining a scope	*1. Check for related research questions*	narrowed informal research interest	3	know what previous scholarly works already covered
			4	know what previous scholarly works were missing
	2. Refine scientific interest	specific research question	5	use specific vocabulary
			6	state a clear scope
			7	state a clear perspective
	3. Formulate Search Query	preliminary weighted keywords and queries	8	use relevant keywords
			9	weight individual keywords
	4. Refine with related literature	weighted keywords and refined queries	10	extend the vocabulary
			11	identify polysemes and synonyms
			12	validate research questions
	5. Reevaluate with domain experts	validated weighted keywords and queries	13	validate keywords
			14	validate weights
			15	validate search query

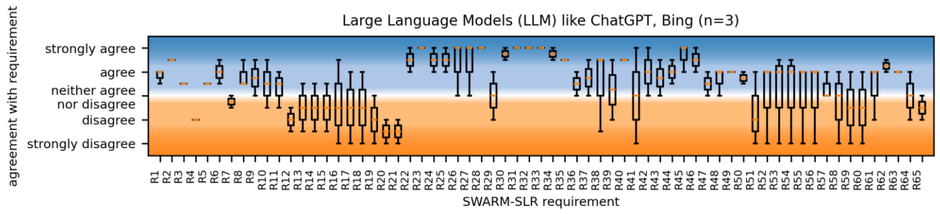
Table 3: SWARM-SLR requirements of stage II

Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
3. Search	*1. Find resources*	preliminary document set	16	use reliable sources
			17	find relevant documents
			18	find similar documents
	2. Remove duplicates and find missing documents	curated document set	19	identify duplicate documents
			20	find unindexed documents
			21	identify document set gaps
4. Select	*1. Extract structured data from documents*	metadata	22	extract publication date
			23	extract author(s)
			24	extract publication venue
			25	extract specified keywords
		content	26	extract document text
			27	differentiate chapters
		bag of words	28	remove special character
			29	identify multi-words
			30	expand acronyms
			31	lemmatize words
			32	normalize words
			33	remove stop words
		contribution statements	34	identify statements
	2. Calculate relational measurements within the document set	document representation	35	calculate "term frequency" (tf) and "term frequency - inverse document frequency" (tf-idf)
			36	calculate word embedding and document embedding
			37	represent document machine-readable
		similarity of documents within the document set	38	consider synonyms
			39	consider polysemes
			40	calculate document similarity
	3. Identify documents relevant for the research questions	relevance of documents for research question	41	represent research question machine-readable
			42	calculate document relevancy for research question
5. Eval -uate	*1. Remove out-of-scope document subset*	in-scope document set	43	define in-/exclusion criteria
			44	exclude documents
	2. Evaluate relevancy measurement	selection approval	45	evaluate similarity of documents
			46	evaluate relevance of documents
	3. Classify document subsets	literature subsets	47	calculate variables
			48	divide document set into subsets

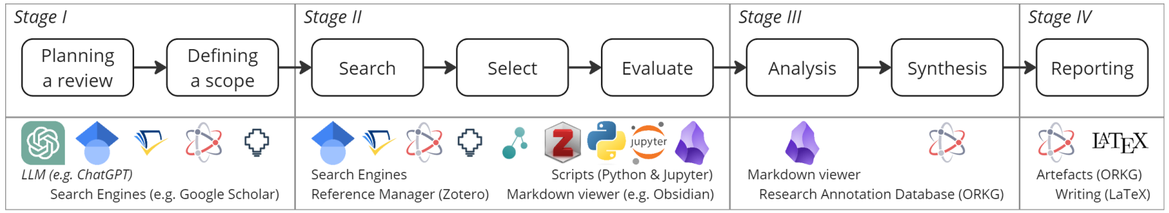
Table 4: SWARM-SLR requirements of stage III and IV

Task	Step	Result	ID	**Requirement:** The tool should be able to help the user to efficiently ... for the <result>.
6. Analysis	*1. Annotate resources*	contribution representation	49	annotate the document
			50	represent the annotation machine-readable
			51	annotate collaboratively
7. Synthesis	*1. Compare contributions*	comparison	52	define comparison properties
			53	insert contribution values
	2. Craft arguments based on findings	document claims	54	identify evidence (data)
			55	establish warrant
		thesis claims	56	identify evidence (claims)
	3. Critique the literature		57	identify patterns
			58	detect fallacies
			59	identify conflicts
			60	resolve conflicts
8. Reporting	*1. Write the literature review*	review article	61	utilize comparisons
			62	support claims
			63	establish outline
			64	draft iteration(s)
			65	audit iteration(s)

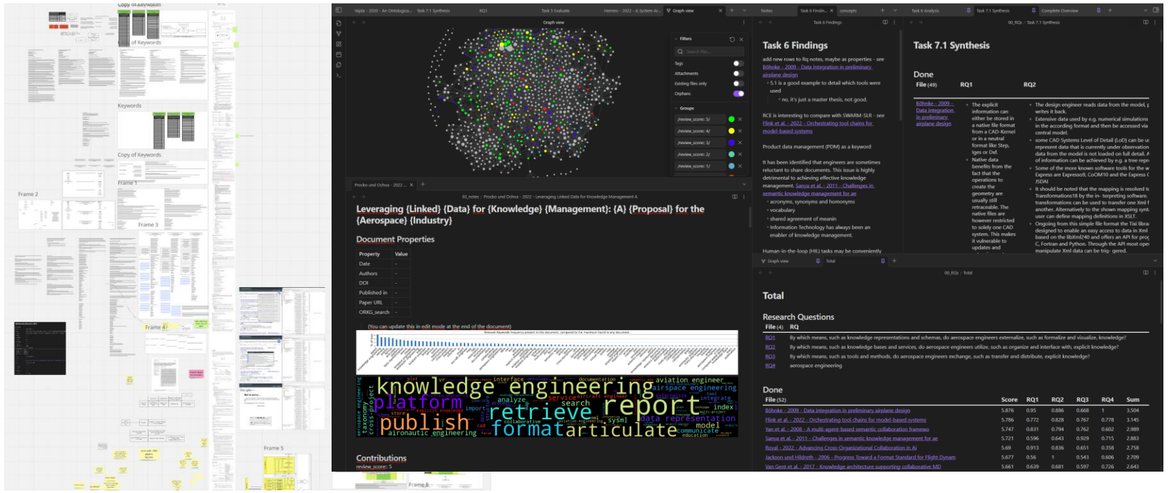
12 Tools assessed



1 modular Workflow synthesized



Ready-to-use SWARM-SLR, but no full SRA



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