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Knowledge Graph-based System for Technical Document Retrieval

A deductive reasoning-focused exploration

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RESPONDING THESIS

Knowledge Graph-based System for Technical Document Retrieval
A deductive reasoning-focused exploration

- Research objective: Leveraging domain knowledge to enhance Information Retrieval in a technical context.
- CIFRE contract (financed by ANRT) between the Litis lab and the company Traceparts
- Began on March 15th 2021.

From a keyword-based search to a concept-based one.

Traceparts

One of the world's leading CAD-content platforms for Engineering, Industrial Equipment and Machine Design. The CAD-content platform traceparts.com provides access to over 1.8 thousand supplier-certified product catalogues with 2D drawings, 3D CAD models and product datasheets.

- Technical content aimed at an engineering audience from multiple industries
- Content available in 25 languages
- Users can search using :
  - A full text search
  - A list of catalogues
  - Different classifications

traceparts
Product Content Everywhere™

Table of content

1. Related works
2. Knowledge Graph-Based System (KGBS)
3. Application context
4. KG-based Information Retrieval
5. Experiments
6. Conclusion and future works

Information Retrieval

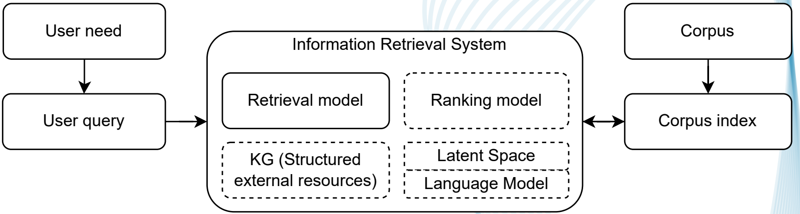


Figure: Information Retrieval System overview

Traditional approaches leverage statistics about the text corpus. Recent methods implement deep learning models and combines multiple approaches.

BM25

BM25 (and its many variants) is:

- based on the Term Frequencies and Inverse Document Frequencies (TF-IDF)
- still widely used in practice
- computes many statistics offline

Traceparts search system is largely based on a BM25 implementation.

Knowledge Graph and ontology

Knowledge Graph (Hogan et. al. 2021): *a knowledge graph is a graph of data intended to accumulate and convey knowledge of the real world, whose nodes represent entities of interest and whose edges represent relations between these entities.*
Ontology (Hogan et. al. 2021): *In the context of computing, an ontology is then a concrete, formal representation of what terms mean within the scope in which they are used (e.g., a given domain).*

In our work, we consider an ontology a particular component of a Knowledge Graph

Knowledge Acquisition

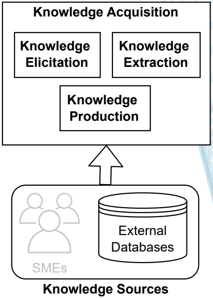


Figure: KGBS: Knowledge acquisition

Knowledge modeling

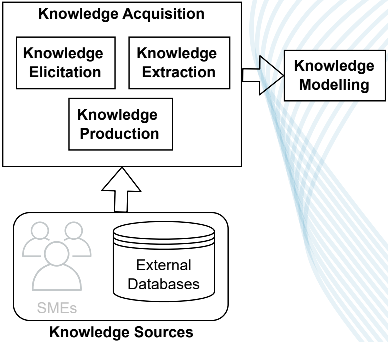


Figure: KGBS: Knowledge modeling

Knowledge Graph

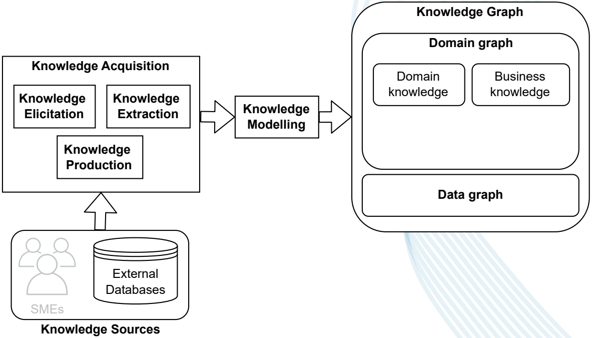


Figure: KGBS: Knowledge Graph

Knowledge consumption

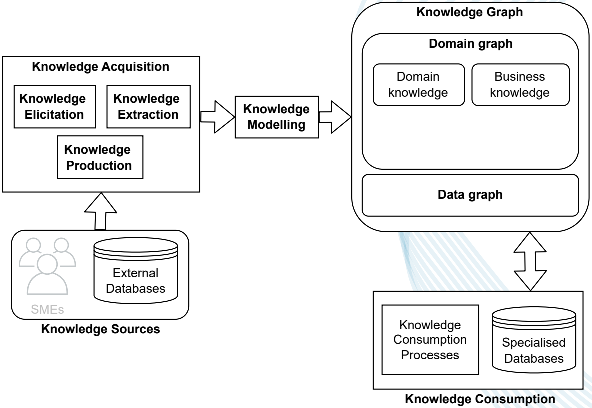


Figure: KGBS: knowledge consumption

Knowledge Graph-Based System architecture

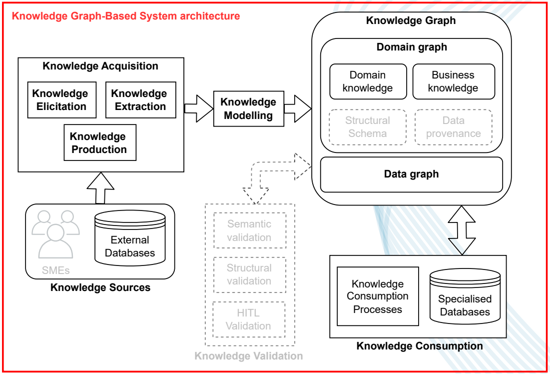


Figure: KGBS architecture

Ontology Learning Applied Framework (OLAF)

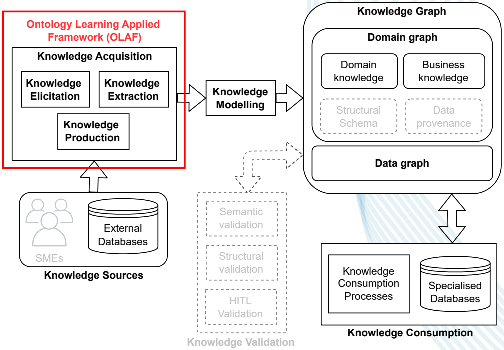


Figure: KGBS architecture: OLAF

Information Retrieval ontology

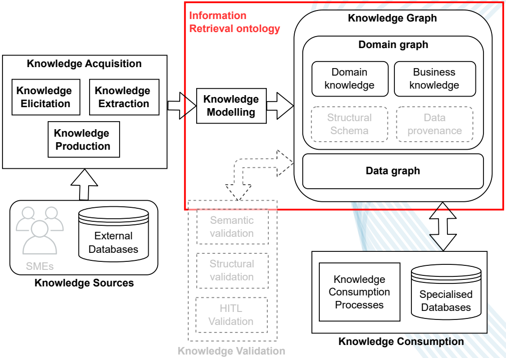


Figure: KGBS architecture: IR ontology

Industrial experiments

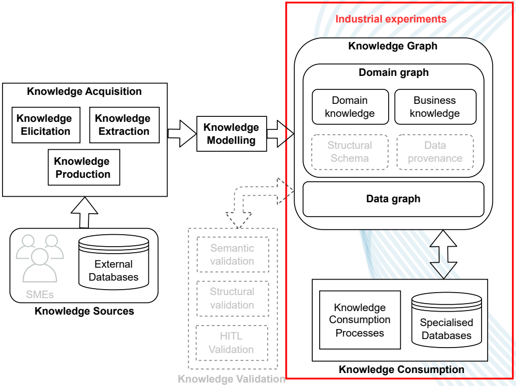


Figure: KGBS architecture: Industrial experiments

In this presentation

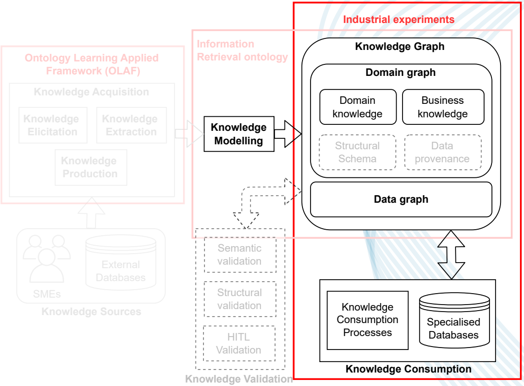


Figure: This presentation KGBS architecture components focus

Corpus

- Over 1.1 million Document Families
- Over 127.8 millions individual documents
- 25 languages
- Documents' texts contain average 50 characters and 7 words
- Over 210 thousand tags, amongst which:
  - Over 2.5 thousand suppliers and manufacturers
  - Over 1.9 thousand catalogues
  - Over 208 thousand categories

Some text content examples are:

- *DIN 912*
- *The P01 to P08 pumps are designed to pump lubricating fluids (oil, diesel oil, etc.). Their flow rate is from 1 to 24 L / min; maximum working pressure 10 bar.*

User searches

User text searches:

- are composed of domain-specific keywords, notations, identifiers, and acronyms.
- contain on average 13 characters separated into 2 words.
- can come in any languages

Some common search examples are:

motor, *din 912*, and *ball valve*.

Traceparts search system challenges

Traceparts search challenges come from:

- Short multilingual texts
- Technical texts with many synonyms, acronyms, homonyms, and notations
- A large and heterogeneous corpus
- Multiple engineering domains coverage
- High recall but low precision

Experiments objective

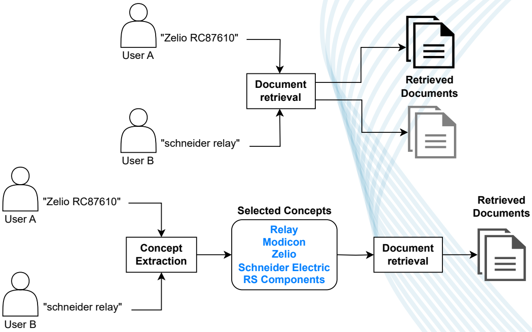
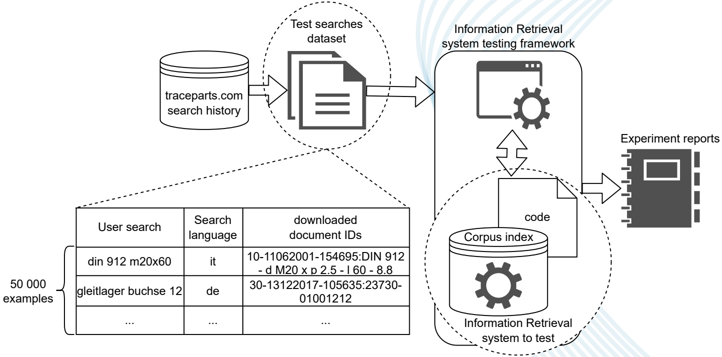


Figure: Text-based vs concept-based search.

Evaluation metrics

- Mean Average Precision at k (MAP@k):
  - A sliding (or growing) precision window, averaged over a set of query examples.
  - Ranges from 0 to 1 (1 is the best value).
  - Gives information about the amount and positions of positive results in the k first ones.
- Binary Mean at k (BM@k):
  - Binary average over a set of query examples.
  - Ranges from 0 to 1 (1 is the best value).
  - Provides information about the amount of queries with a positive result in the k first ones.
  - Does not give any detail on the positive result position.

Experiments protocol



User search	Search language	downloaded document IDs
din 912 m20x60	it	10-11062001-154695:DIN 912 - d M20 x p 2.5 - l 60 - 8.8
gleitlager buchse 12	de	30-13122017-105635:23730-01001212
...	...	...

Figure: Experiments Protocol.

Experiments

6 distinct systems built iteratively:

- *Text-based system (baseline)*
- **Concept-based system**
- Knowledge Graph-based system
- Text-based system with implicit knowledge
- Concept-based system with implicit knowledge
- **Knowledge Graph-based system with implicit knowledge**

Systems implementations:

- User search concept matching problem as an information retrieval task.
- Leverage user search history as implicit knowledge.
- Query concept enrichment as a graph traversal task.

Text-based system (baseline)

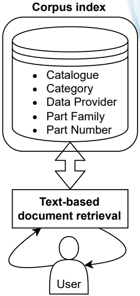


Figure: Text-based system (baseline)

Text-based system (baseline) results

	Text-based system (baseline)	
@k ↓	**MAP@k**	**BM@k**
@5	0.061	0.114
@25	0.064	0.148
@50	0.064	0.157
@100	0.064	0.161
@350	0.064	0.164

Table: Text-based system (baseline) results for different k values.

Concept-based system

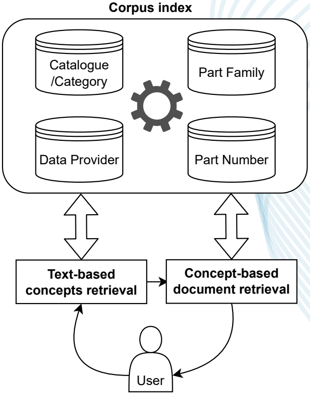


Figure – Concept-based syst

Concept-based system results

	Text-based system (baseline)		Concept-based system	
@k ↓	**MAP@k**	**BM@k**	**MAP@k**	**BM@k**
@5	0.061	0.114	0.152	0.243
@25	0.064	0.148	0.159	0.334
@50	0.064	0.157	0.160	0.371
@100	0.064	0.161	0.161	0.403
@350	0.064	0.164	0.161	0.429

Table: Text and concept-based systems results for different k values.

Knowledge Graph-based system with implicit knowledge

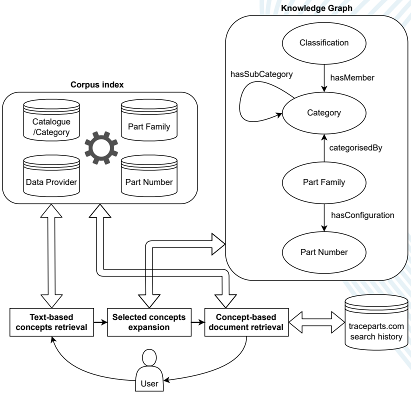


Figure: Knowledge Graph-based system with implicit knowledge

Knowledge Graph-based system with implicit knowledge results

	Text-based system (baseline)		Concept-based system		KG-based system with search history	
@k ↓	**MAP@k**	**BM@k**	**MAP@k**	**BM@k**	**MAP@k**	**BM@k**
@5	0.061	0.114	0.152	0.243	0.115	**0.291**
@25	0.064	0.148	0.159	0.334	0.122	**0.471**
@50	0.064	0.157	0.160	0.371	0.123	**0.552**
@100	0.064	0.161	0.161	0.403	0.123	**0.624**
@350	0.064	0.164	0.161	0.429	0.124	**0.715**

Table: Text, concept, and KG-based systems results for different k values.

Quantitative results

	No results	Less than 400 results (non empty)
Text-based system (baseline)	64.48%	35.44%
Concept-based system	11.43%	**88.36%**
KG-based system with search history	**8.10%**	51.59%

Table: Comparing all search systems results set corpus.

Contributions

A top-down approach from a system perspective down to solution implementations.

Contributions:

- A unifying definition of Knowledge Graph
- An architecture for Knowledge Graph-Based Systems
- A framework for Ontology Learning
- An OWL Information Retrieval ontology
- A study of a text-based compared to a Knowledge Graph-based Information Retrieval system

Conclusion

We have explored:

- A Knowledge Graph definition incorporating ontologies
- A Semantic Web-focused implementation of this Knowledge Graph definition
- An OWL Information Retrieval Ontology
- Two Knowledge Graph-based Information Retrieval System approaches:
  - A real-world use case moving from a text-based to a Knowledge Graph-based Information Retrieval System.
  - An online OWL reasoning-based Information Retrieval use case.

Future works

- Knowledge Graph-based Information Retrieval system:
  - Expand the Knowledge Graph
  - Expand the approach to other domains
- OWL reasoning-based Information Retrieval system:
  - Experiment with a real-world use case at scale
  - Explore distinguishing between searches with no matching documents and incoherent ones
- Implement an end-to-end Knowledge Graph-Based System architecture use case.

Perspectives: Knowledge Graph

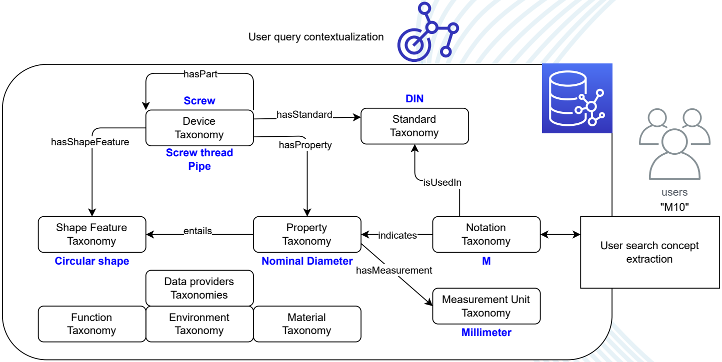


Figure: Extended semantic search example.

Scientific productions

Peer-reviewed international conference papers:

- An operational architecture for knowledge graph-based systems. Proceedings of the 26th International Conference KES2022.
- (with Marion Schaeffer) Olaf: An ontology learning applied framework. Proceedings of the 27th International Conference KES2023.

Open-source software library (with Marion Schaeffer):

- Ontology Learning Applied Framework Python library implementation: https://wikit-ai.github.io/olaf/

Thank you!

Thank you for your attention. I am now ready to answer any questions.