Knowledge Graph-based System for Technical Document Retrieval

A deductive reasoning-focused exploration

PhD student: Matthias SESBOÜÉ
Directed by Cecilia ZANNI-MERK
Supervised by Nicolas DELESTRE and Jean-Philippe KOTOWICZ

September 5, 2024

Table of contents

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.
- Traceparts employment partially financed by ANRT as part of a CIFRE research project in collaboration with the Litis lab.
- Began on March 15th 2021.

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™

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 language

The most common searches are:

- *motor*
- *din 912*
- *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

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

Our approach based on a Knowledge Graph

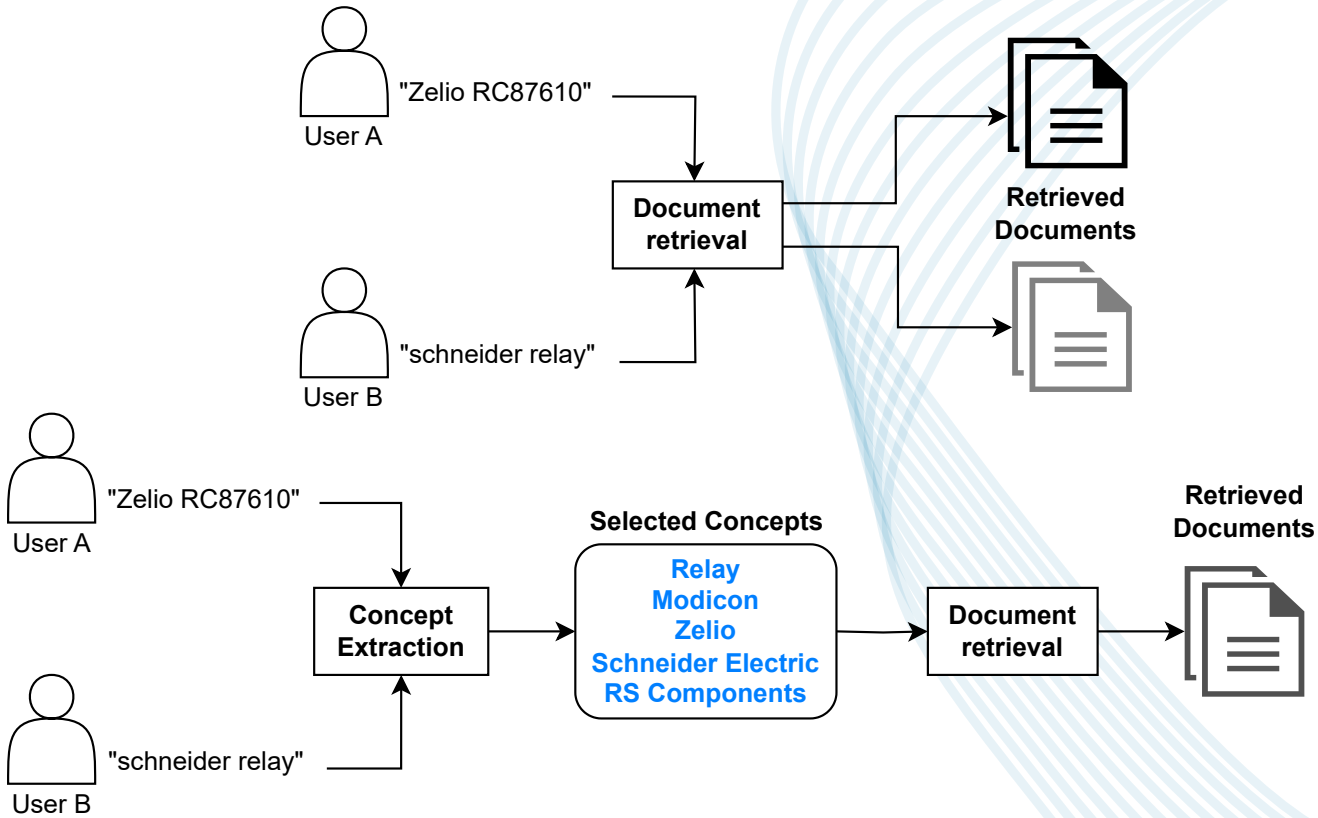


Figure: Text-based vs concept-based search.

Evaluation corpus construction

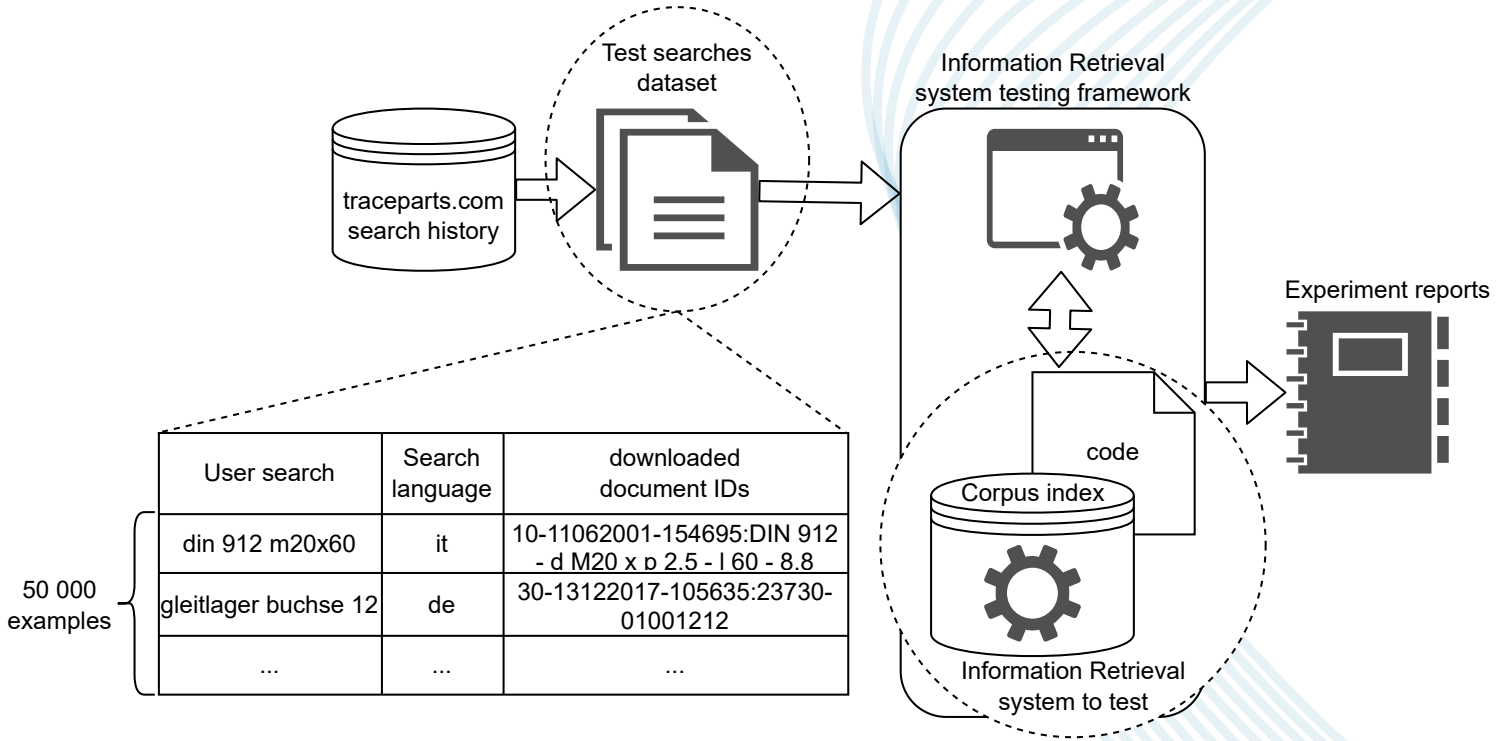
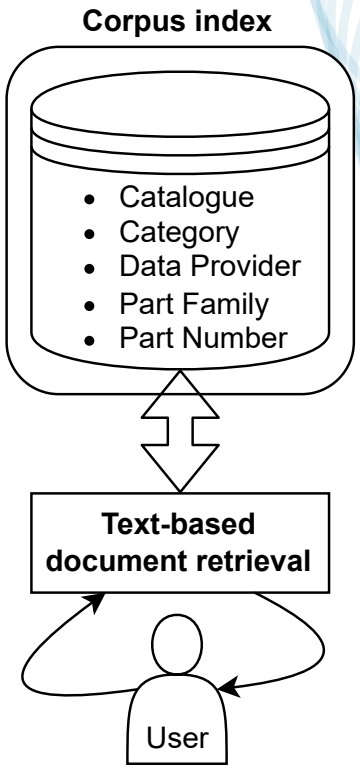


Figure: Experiments Protocol.

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.

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.

Knowledge Acquisition

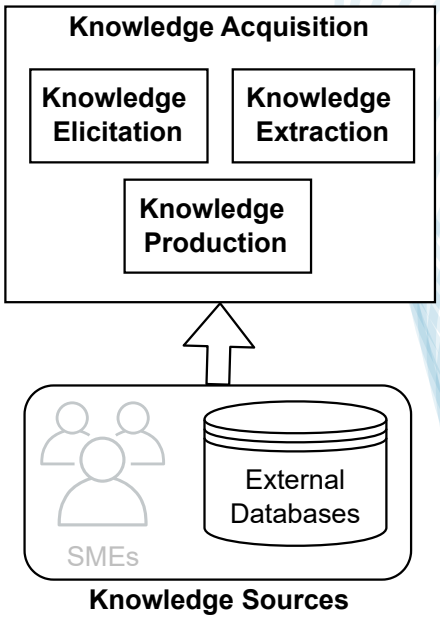


Figure: KGBS: Knowledge acquisition

Knowledge Graph

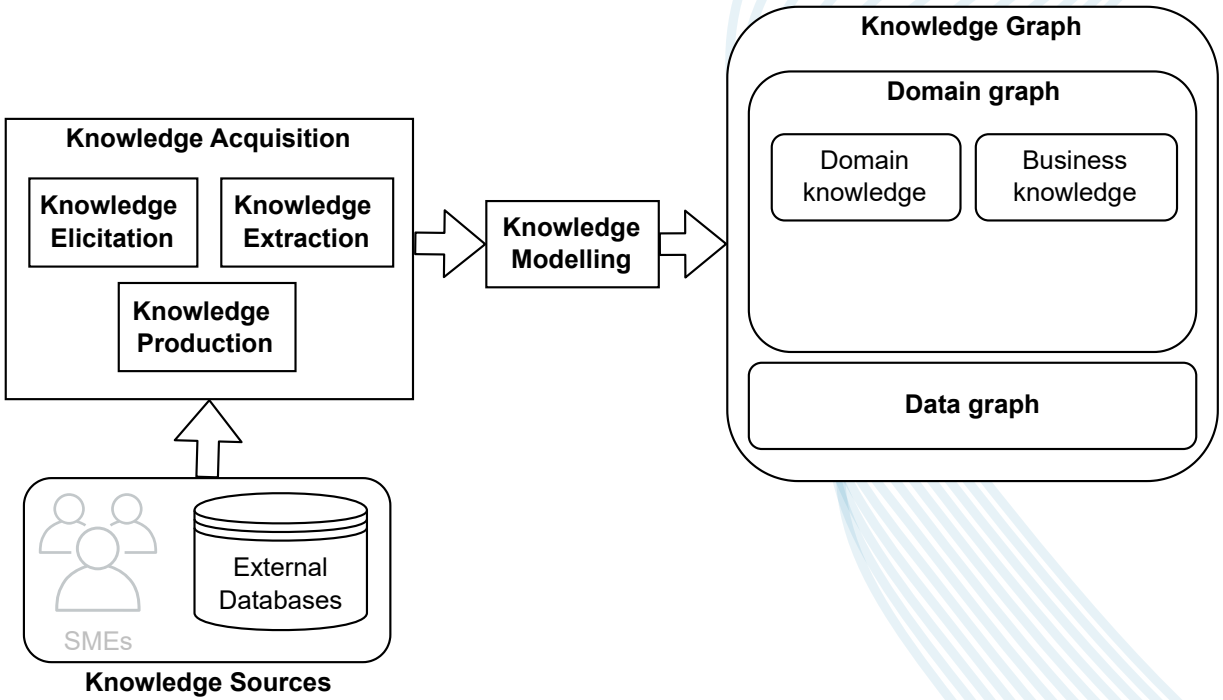


Figure: KGBS: Knowledge Graph

Knowledge consumption

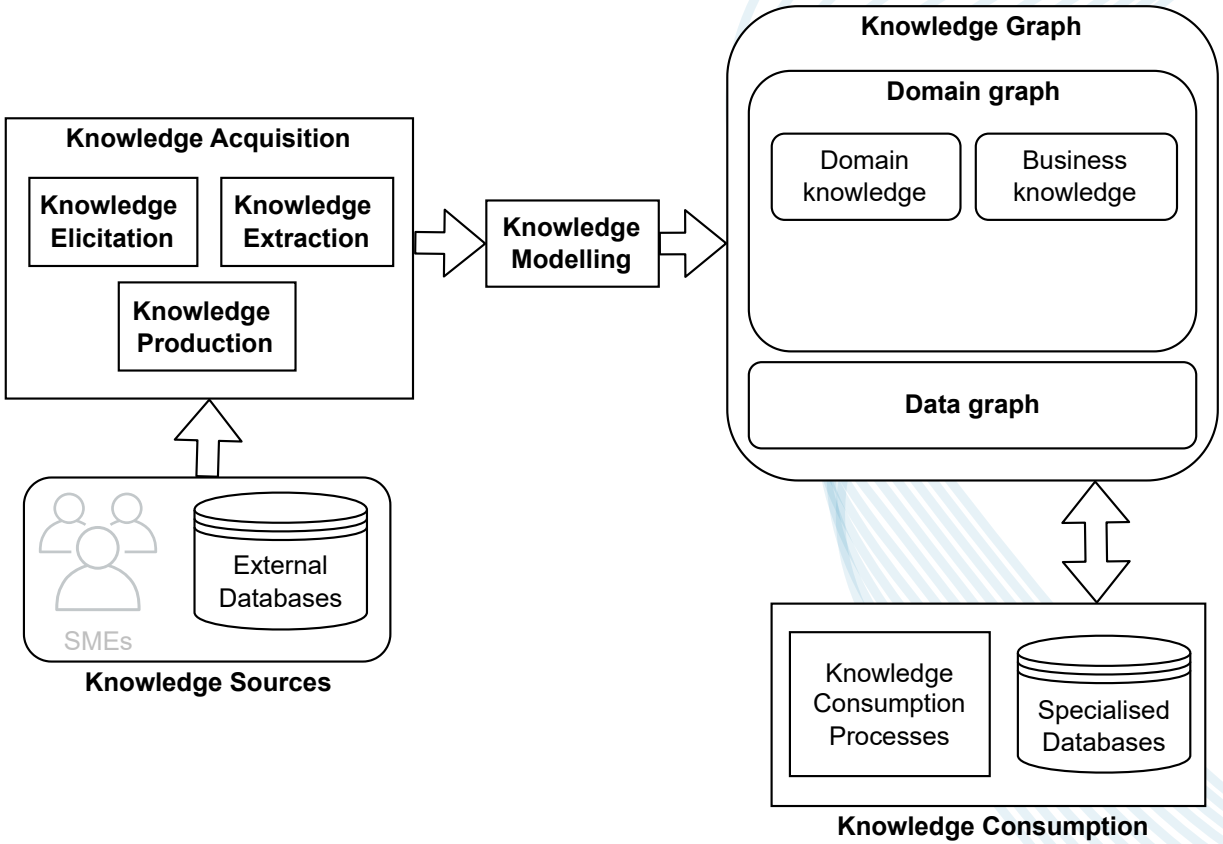


Figure: KGBS: knowledge consumption

Knowledge Graph-Based System architecture

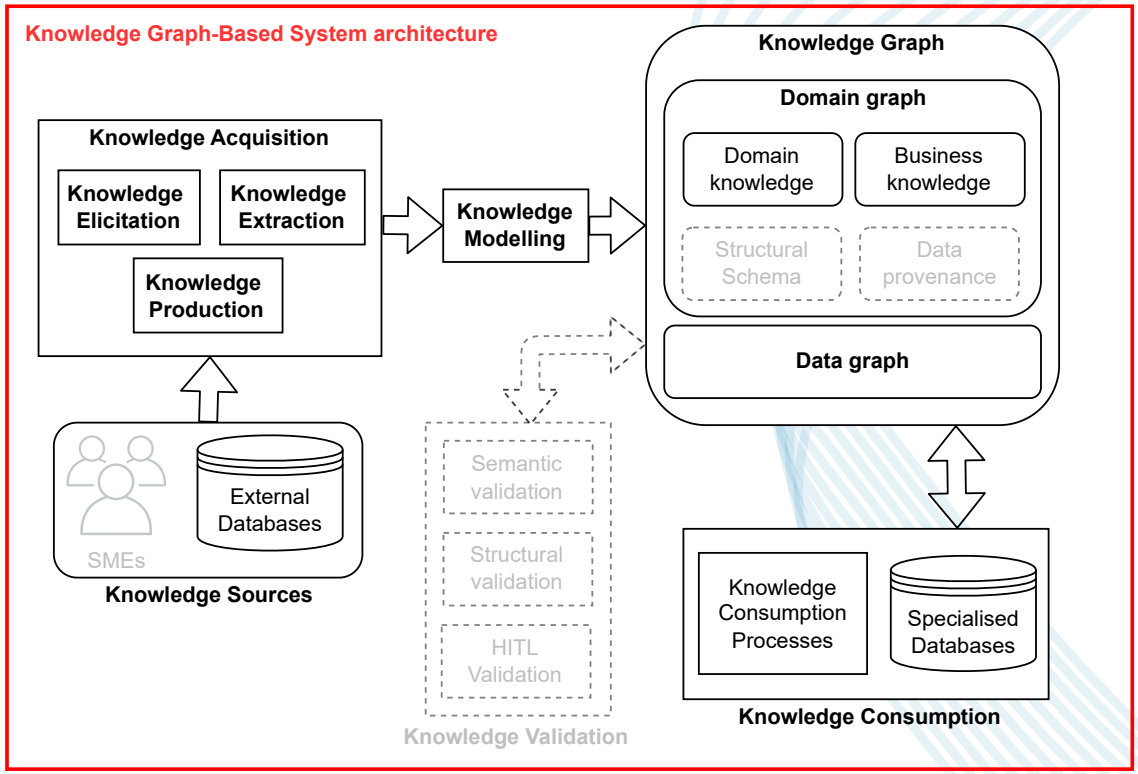


Figure: KGBS architecture

Ontology Learning Applied Framework (OLAF)

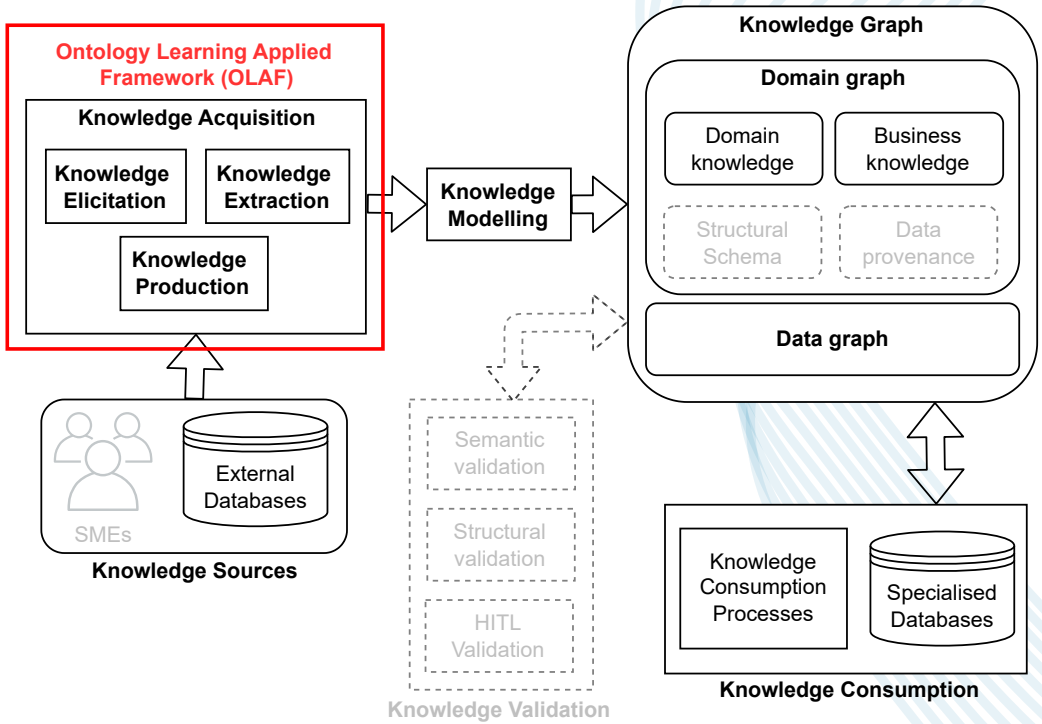


Figure: KGBS architecture: OLAF

Information Retrieval ontology

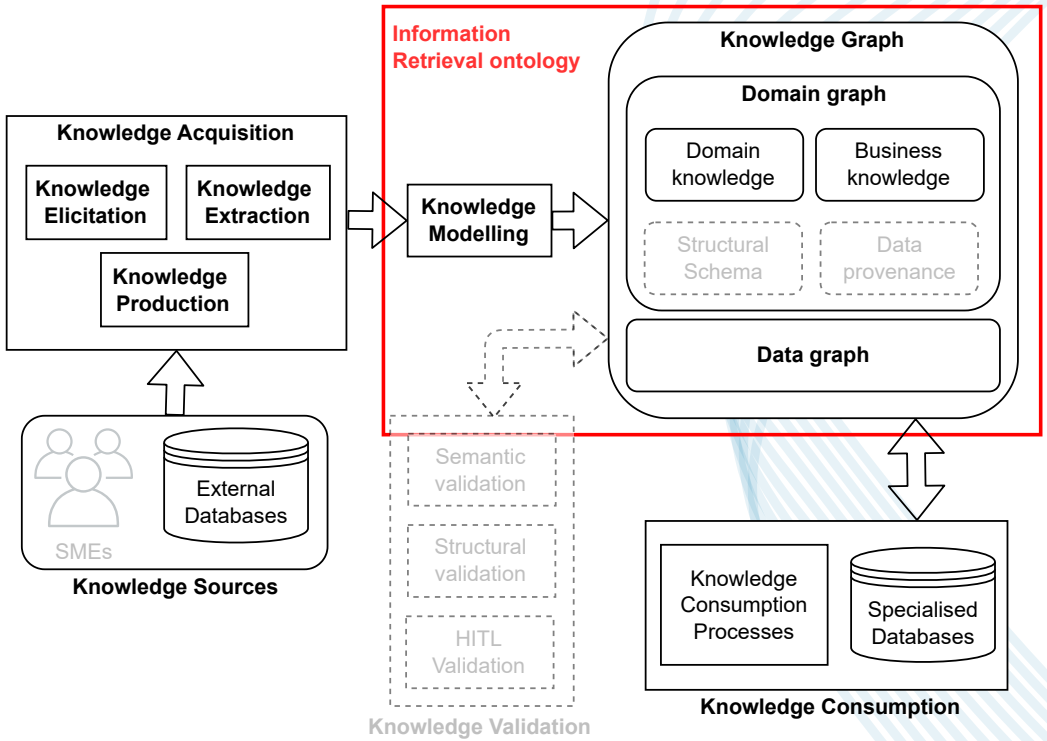


Figure: KGBS architecture: IR ontology

KG-based Information Retrieval

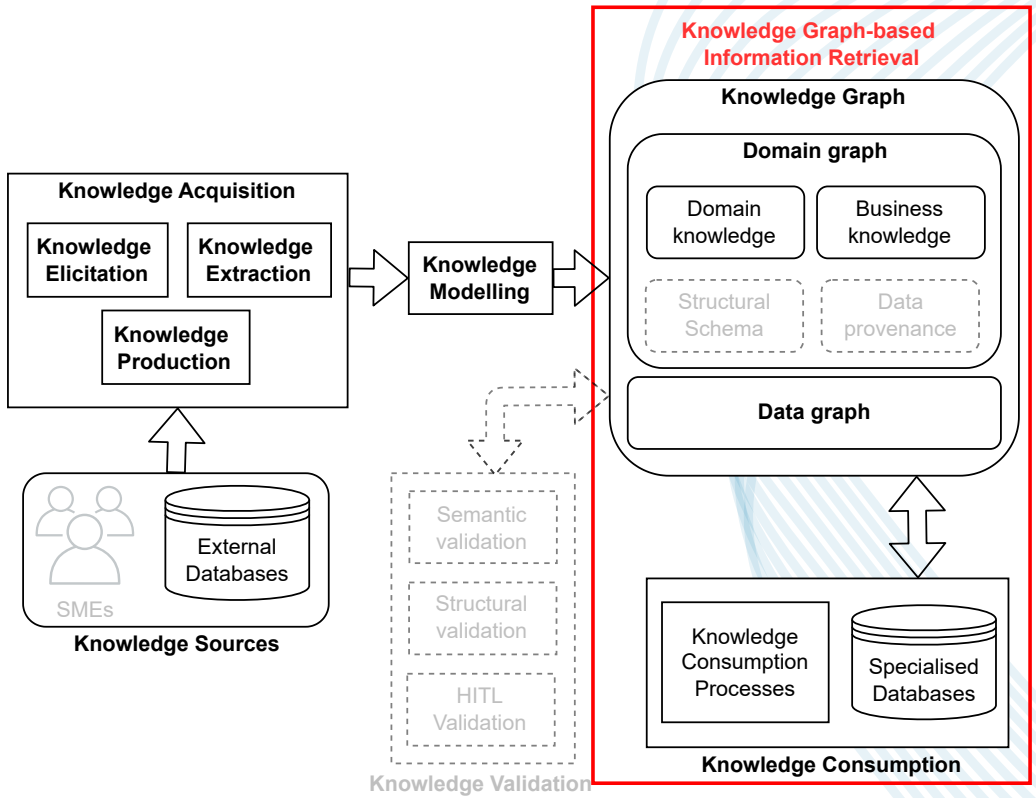


Figure: KGBS architecture: Industrial experiments

In this presentation

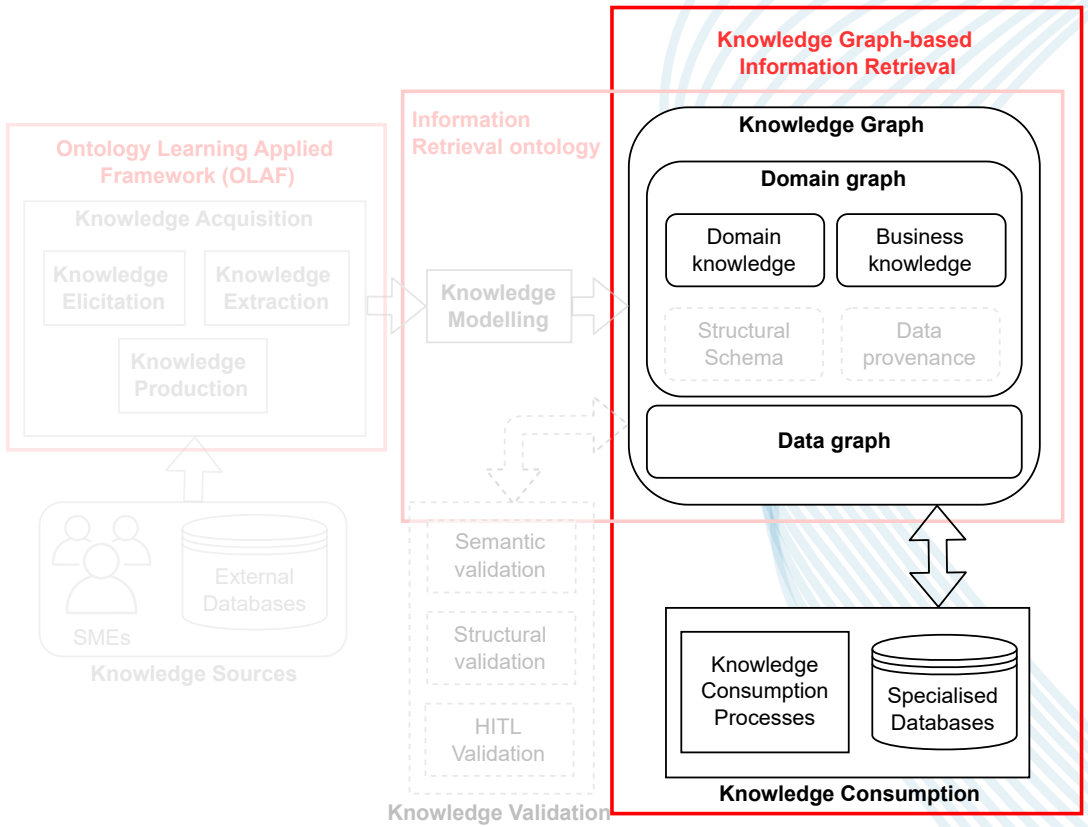


Figure: This presentation KGBS architecture components focus

Traceparts Knowledge Graph

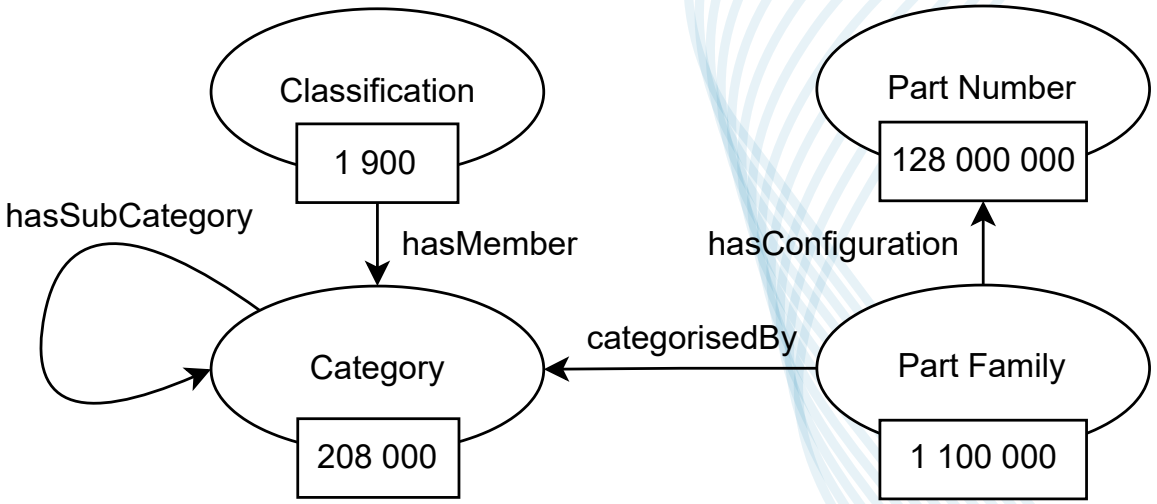
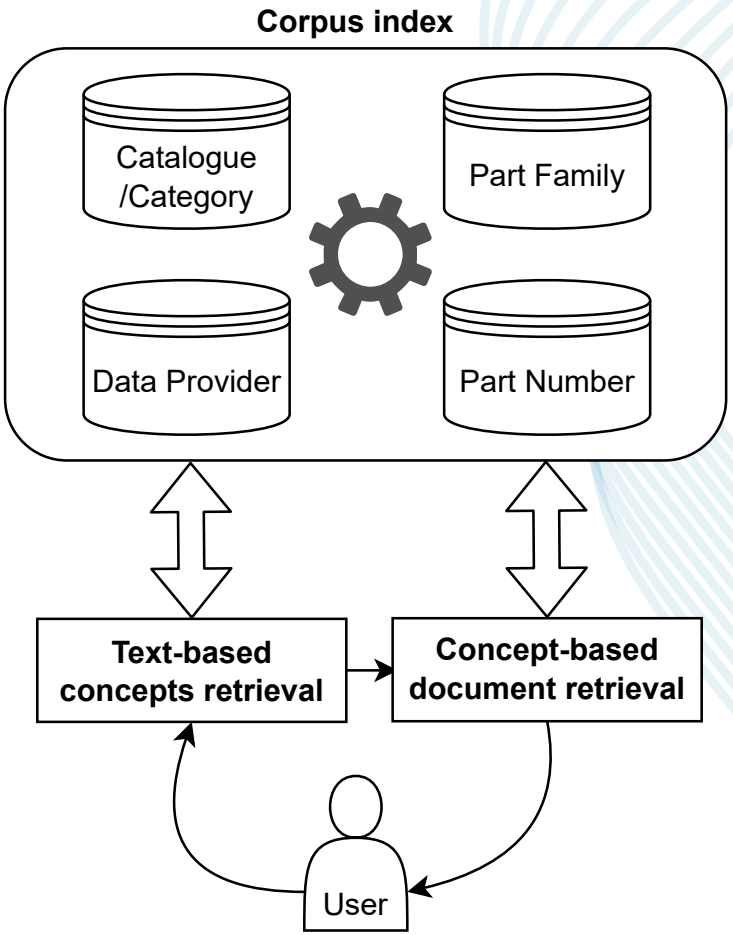


Figure: Traceparts Knowledge Graph

Concept-based system



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.

KG-based system with implicit knowledge

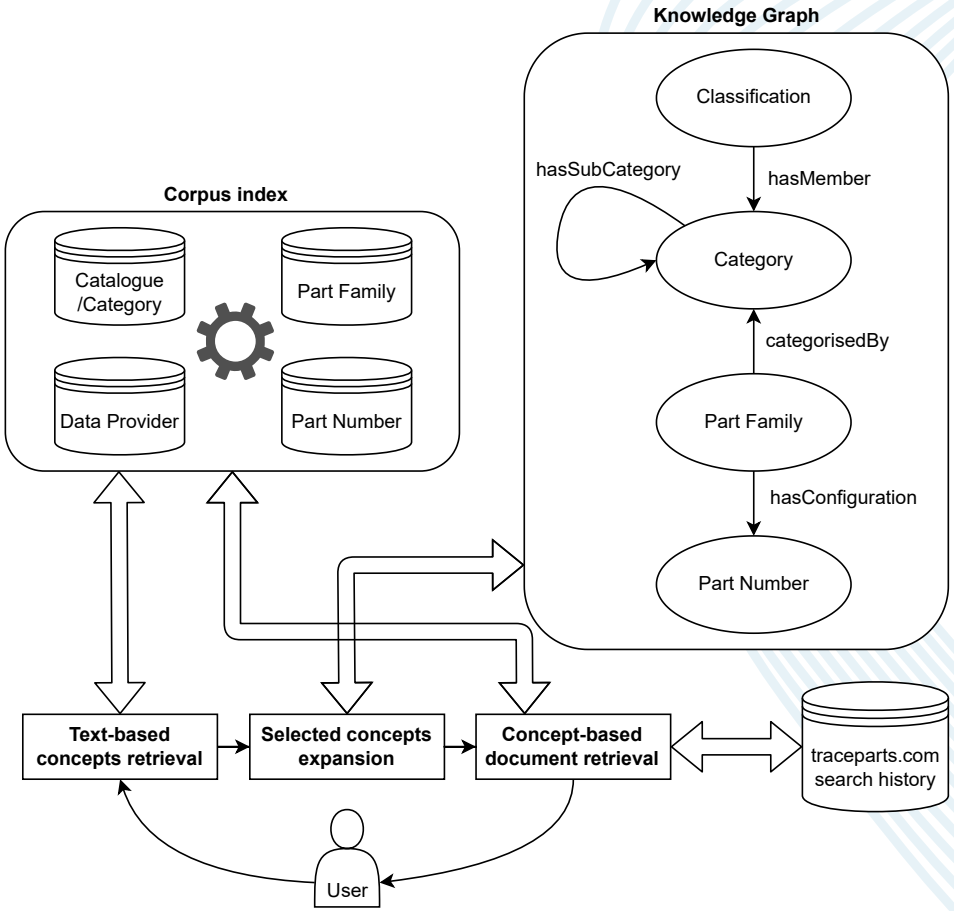


Figure: KG-based system with implicit knowledge

KG-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.

Conclusion

We have:

- Explored a Knowledge Graph-Based System (KGBS) architecture
- Detailed each KGBS containers and activities
- Explored a real-world use case moving from a text-based to a KG-based Information Retrieval (IR) System.
- Introduce and compared 3 IR systems:
  - A text-based IR system
  - A concept-based IR system
  - A KG-based IR system

KG-based systems for IR on a multilingual corpus of technical documents show promising results overcoming the text-based approaches limitations.

Future works

- KGBS architecture:
  - Implement an end-to-end Knowledge Graph-Based System architecture use case.
  - Further explore the modularity of the architecture
- Knowledge Graph-based Information Retrieval system:
  - Expand the Knowledge Graph
  - Enhance the concept matching task
  - Expand the approach to other domains

Contributions

Main contributions:

- Ontology Learning Applied Framework (OLAF)
- An OWL Information Retrieval ontology
- Knowledge Graph-based Information Retrieval systems

Satellite contributions

- A unifying definition of Knowledge Graph
- An architecture for Knowledge Graph-Based Systems

Scientific productions

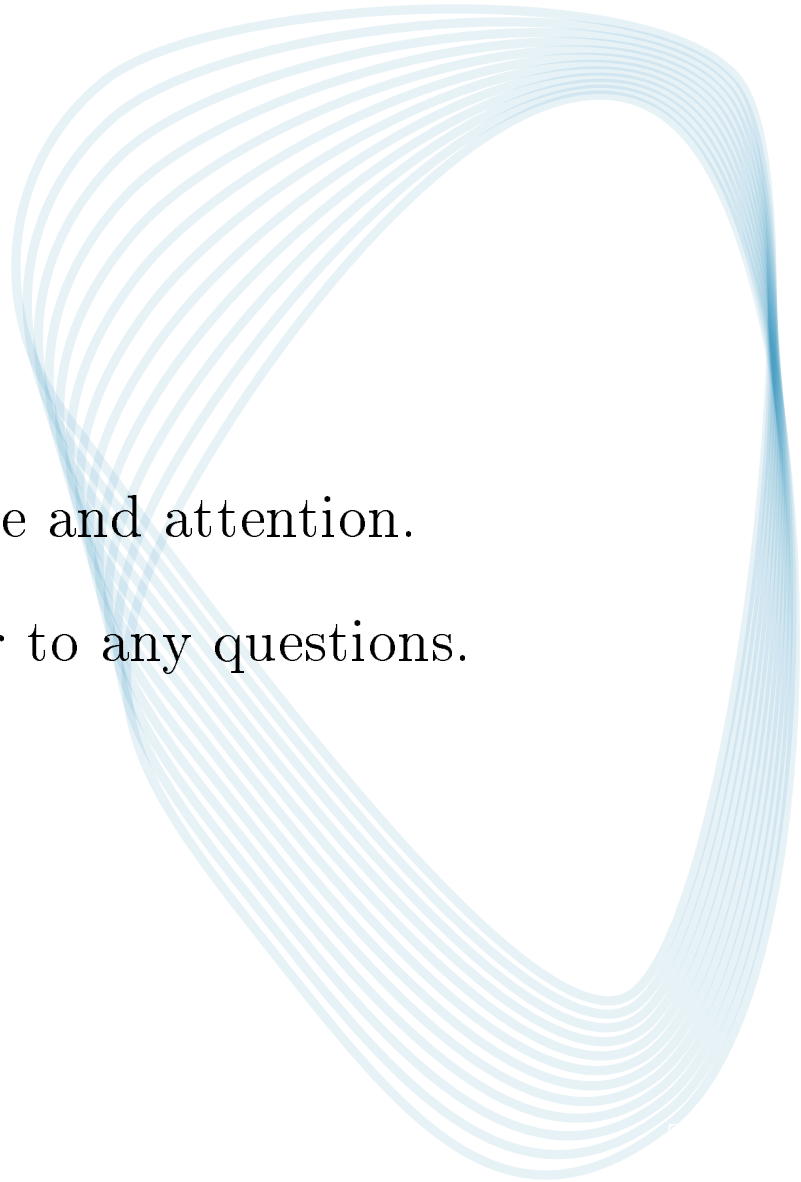
Peer-reviewed international conference papers:

- 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 time and attention.

I am now ready to answer to any questions.

Perspectives: Knowledge Graph

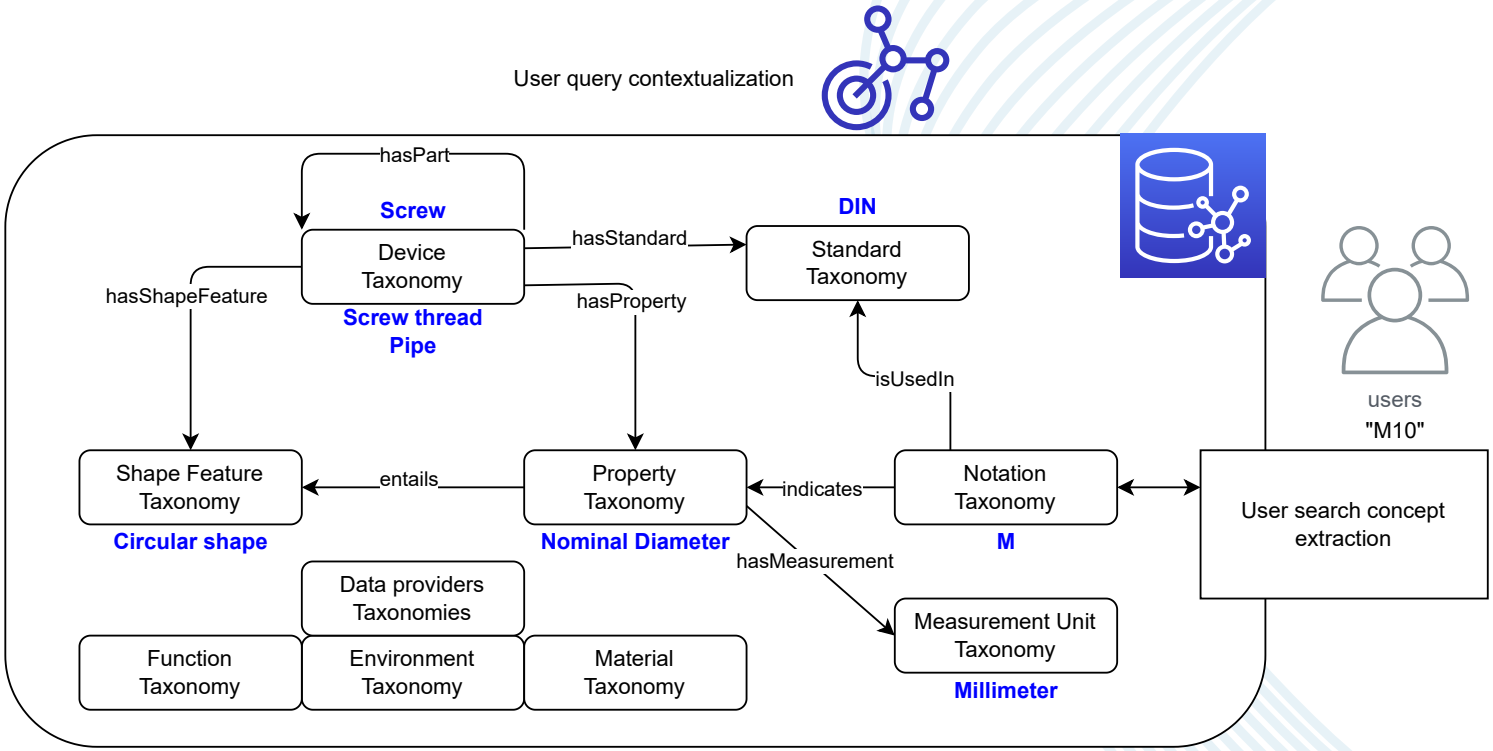
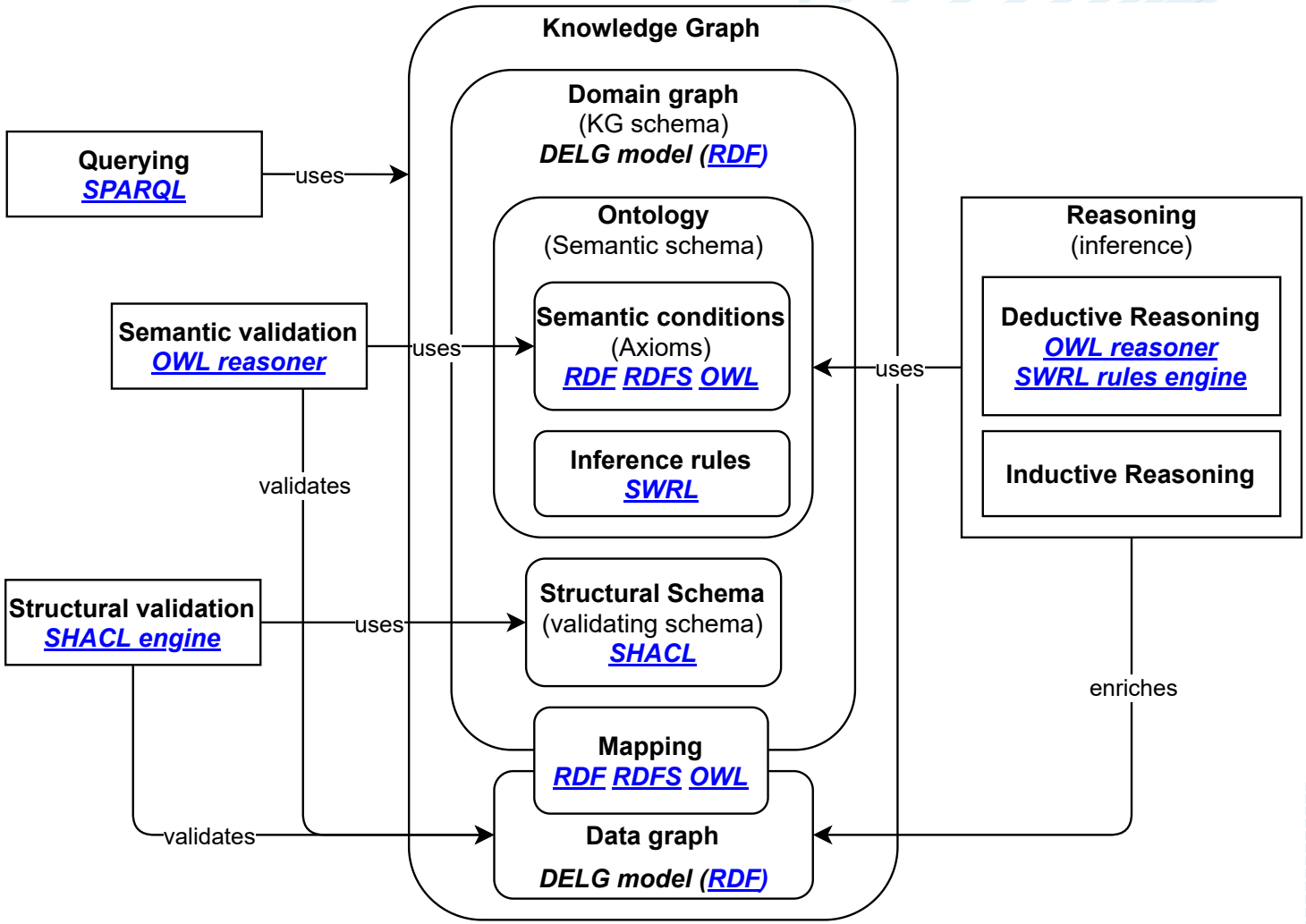


Figure: Extended semantic search example.

Semantic Web Knowledge Graph



Online OWL reasoning-based approach

An approach focusing on OWL.

- An Information Retrieval ontology.
- Push knowledge closer to the data.
- Model domain knowledge as linked sets of taxonomies.

Knowledge modelling

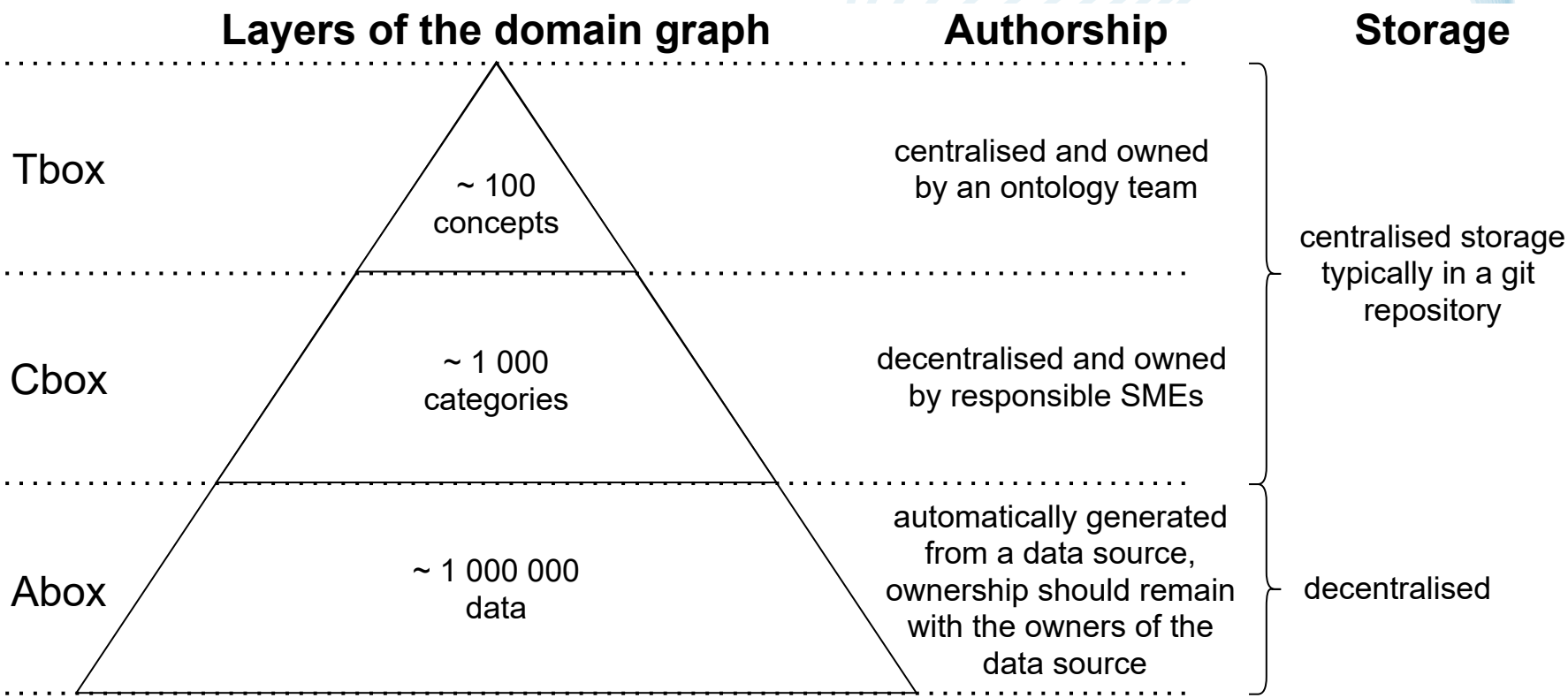


Figure: "C-box" knowledge modelling approach

Information Retrieval Ontology

Competency questions:

- CQ1 What are the categories in the user search?
- CQ2 What are the documents relevant to a search?
- CQ3 What categories are enabled to refine the search?

7 classes:

- *Candidate Document* subclass of *Document*
- *Selected Category* and *Enabled Category* subclasses of *Category*
- *Search Context* subclass of *Search*

6 Object properties:

- *categorises* inverse of *categorised By*
- *has Search Category* subproperty of *enables Category*
- *has Direct Subcategory* subproperty of *has Subcategory*

Pizza ontology

Pizza ontology:

- Well-knowledge ontology built to introduce RDF/RDFS/OWL with examples (and even SHACL)
- Simple ontology with class hierarchies of:
  - Pizzas (has topping, has base)
  - Pizza bases
  - Pizza Toppings
- We use the Pizza ontology for demonstration in interest of time constraints

Pizza ontology Knowledge Graph

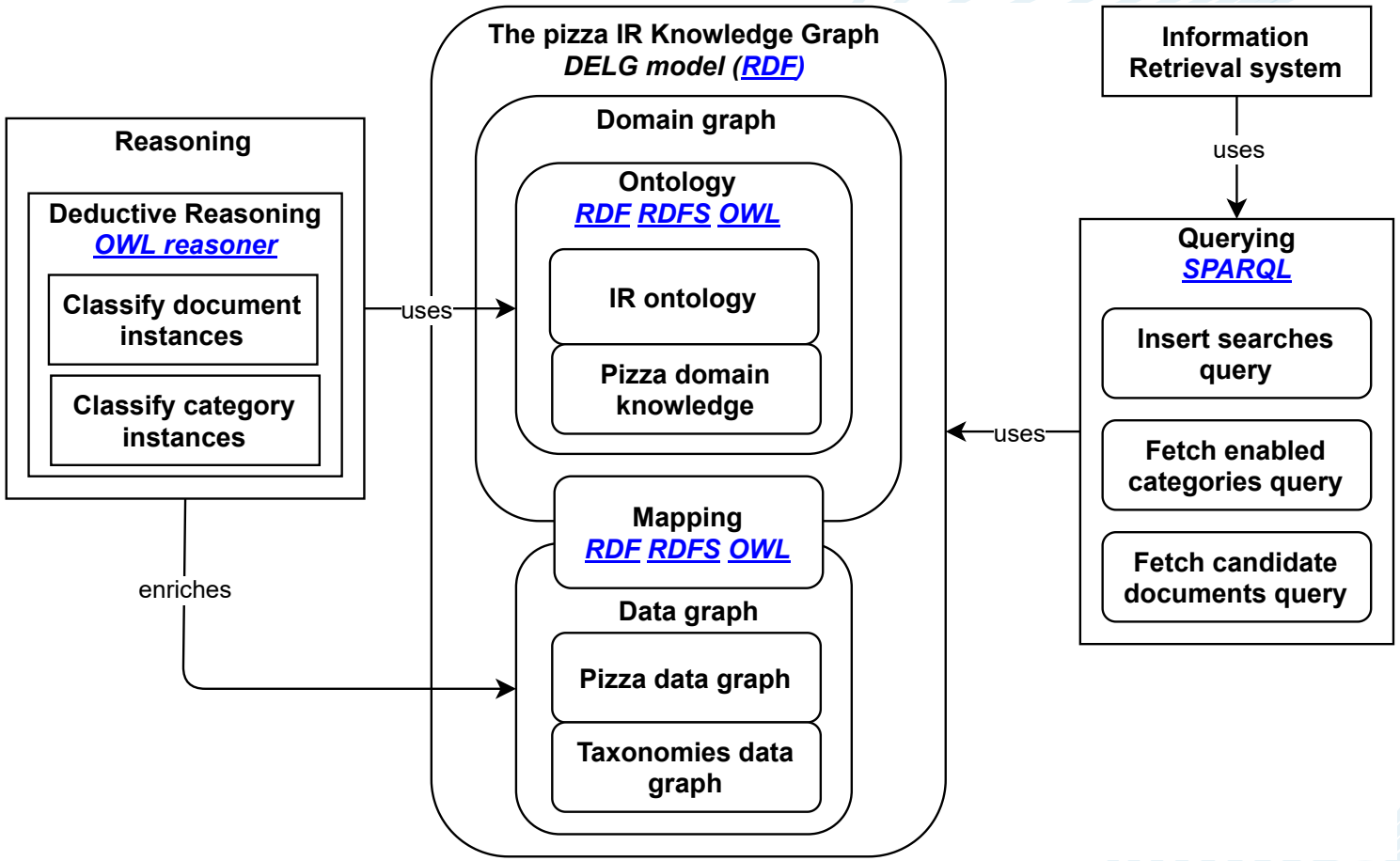


Figure: Pizza ontology Knowledge Graph

OWL reasoning-based Information Retrieval

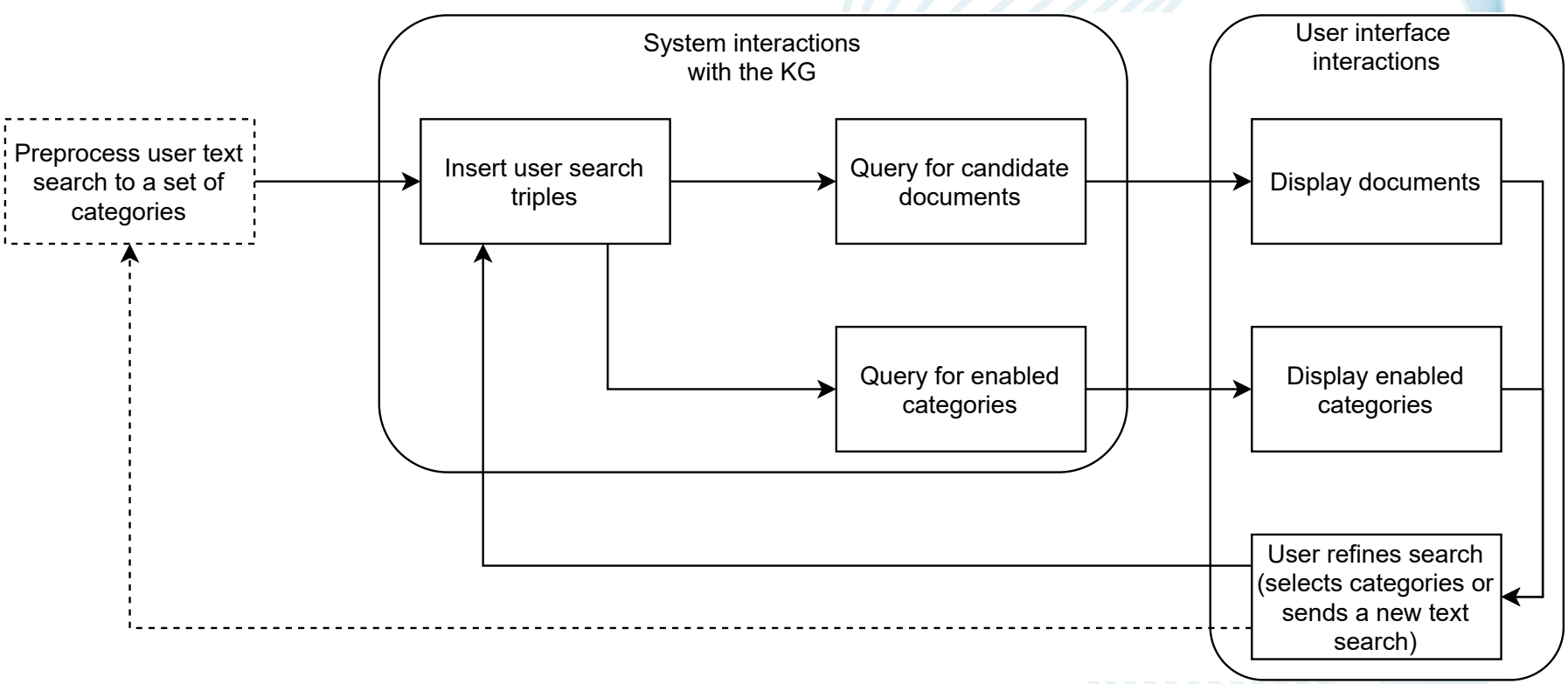


Figure: OWL reasoning-based Information Retrieval process.

Ontology Learning Applied Framework

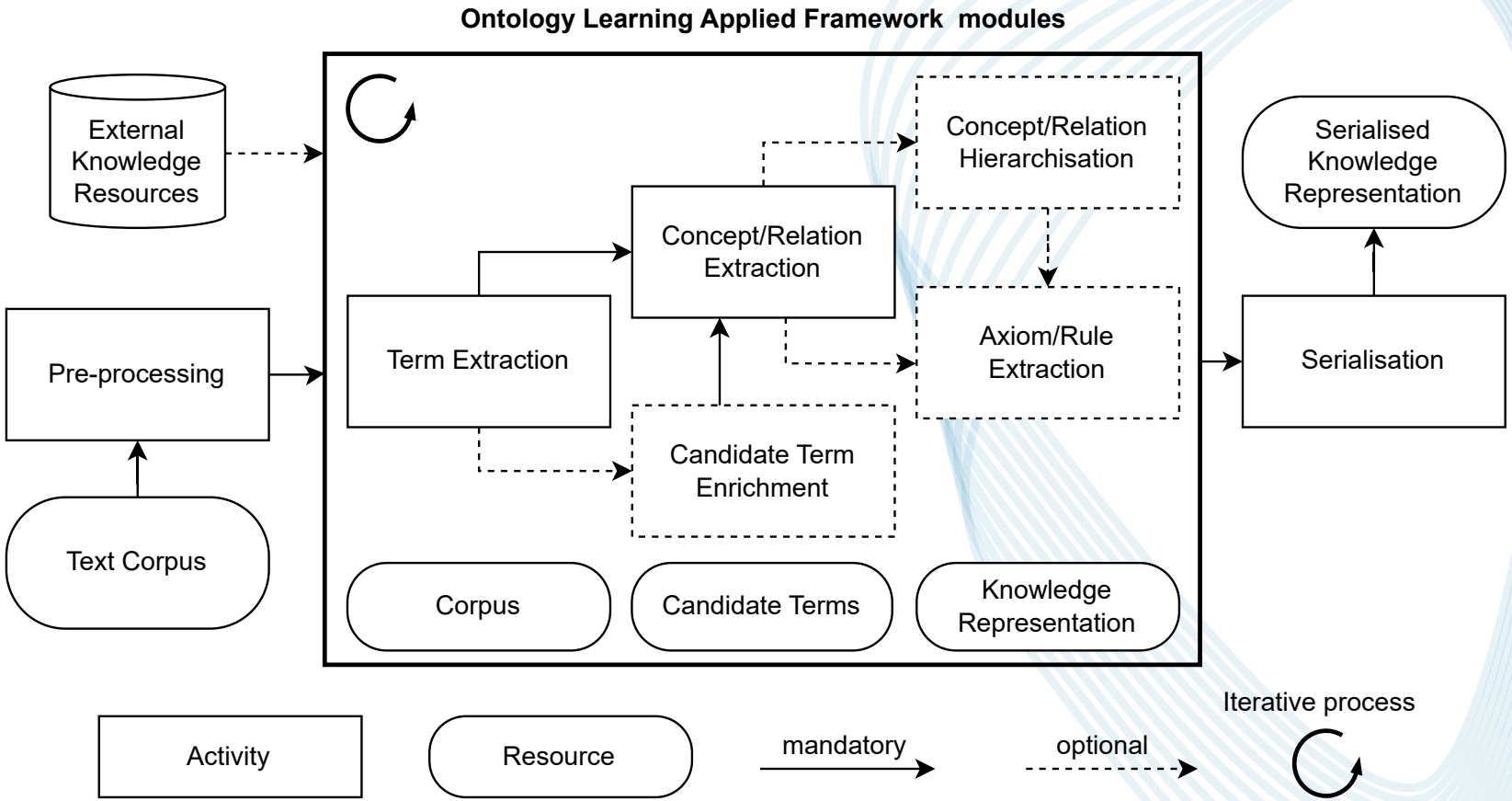


Figure: OLAF modules.

KG-based IR: 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.