

RAGONITE: Iterative Retrieval on Induced Databases and Verbalized RDF for Conversational QA over KGs with RAG

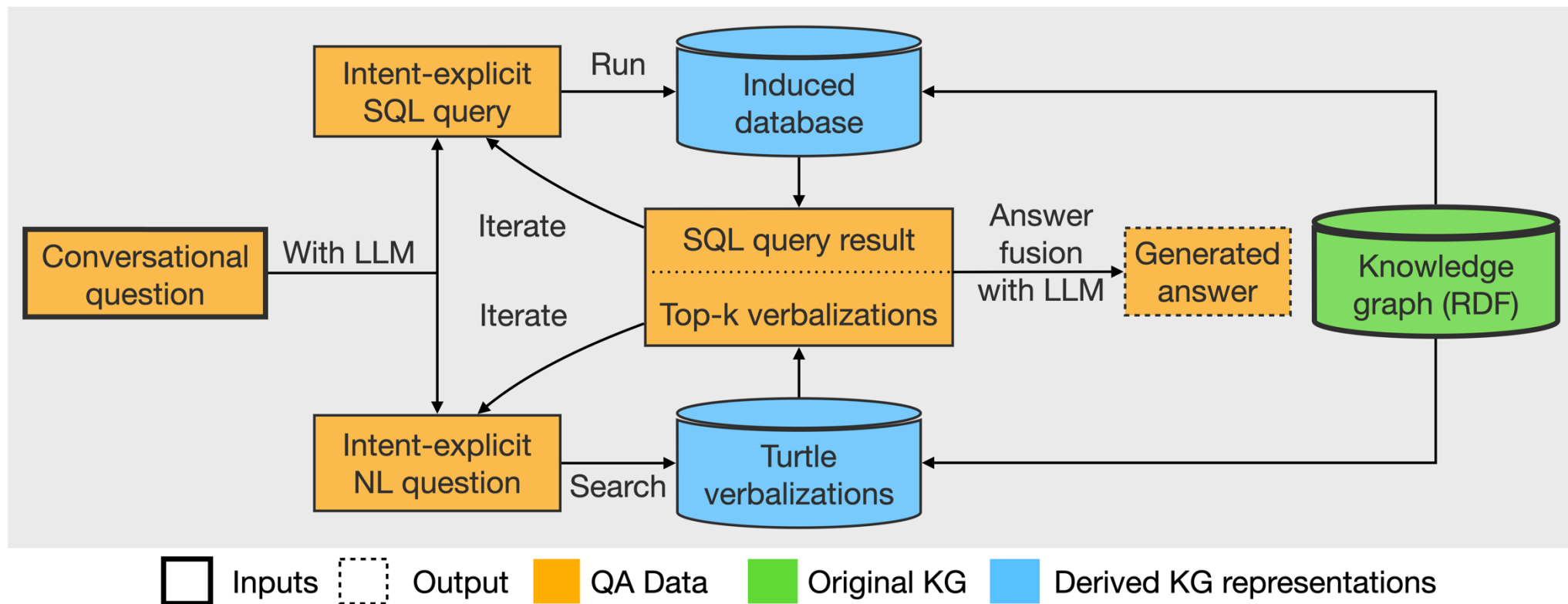
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Make the most of your knowledge graph with RAGONITE!

Demo

Retrieval augmented generation for conversational question answering over knowledge graphs

- Traditional question answering over knowledge graphs with SPARQL only satisfies fact lookups
- Fusing** SQL results over **induced databases** and text search over **RDF verbalizations** unifies lookups, abstract and complex intents on KGs



Use case: Automobile knowledge graphs

Knowledge graph converted to database automatically

- **Database** consists of **several tables** like car types, engines, fuels, accessories, and features
 - Seamless transition to heterogeneous mode if supplementary text documents are available
- Supports **conversational QA** with intent-implicit follow-up questions
 - Precise **fact** lookups (*payloads, top speeds, wheelbases*)
 - **Math** computations (*average height, minimum emissions, price ranges*)
 - More **informal** intents (*comfortable interiors, large boot space, cool highlights*)
- **Two-pronged** methodology
 - LLM-based **SQL query** generation for execution over DB ([Li et al. 2023](#))
 - LLM-based **NL query** generation for hybrid (lexical + dense) search over verbalized DB ([Oguz et al. 2022](#))
- RAGonite probes both branches and **fuses results** to generate final answer
- **Iterative approach** increases robustness to "failed" retrievals
 - SQL execution results or top text results may not satisfy original intent
 - Then retrieval is repeated (max. thrice) with the first round results included in the prompt for the query generation LLM
 - This often helps address more complex intents in a single turn (*average price of x7 cars with climate control*)

Example question 1: Fact lookups satisfied via both branches

Payload of x7 xdrive40d?

RAGONITE BMW ITERATIVE RETRIEVAL

+ New Chat

My Chats

payload of x7 x...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xDrive...

average price of the ...

average price of the i...

payload of x1 sDrive...

payloads of x3 cars?

top speed of x1 sDriv...

payload of x1 sDrive...

do you have payload ...

do you have payload ...

do you have info on t...

payload of x1

wheel colors for x5?

price of x7 cars with ...

height distribution of...

average price of x7 c...

What is the average ...

User

payload of x7 xdrive40d?

Ragonite

The payload of the BMW X7 xDrive40d is 835 kg. [Source 1, Source 2]

User

average price of x7 variants?

Ragonite

The average price of BMW X7 variants is 102,000 euros. [Source 1]

User

cool features?

Ragonite

The BMW X7 boasts several cool features, including:

1. Comfort highlights like 6 seats, automatic climate control with 5-zone control, and a Bowers and Wilkins diamond surround sound system. [Source 2]

2. Innovative highlights such as the BMW Operating System 8, Comfort Access, and smartphone integration. [Source 2]

3. Interior design highlights with aesthetics and technology in the cockpit, glass application CraftedClarity, and a spacious and comfortable rear. [Source 2]

These features emphasize luxury, comfort, and technological innovation in the design of the BMW X7.

Ask Ragonite about BMW cars...

What is the power of the engine of BMW X1 models?

What electric cars does BMW have?

What power do they have?

Which of them produces the least amount of CO2?

payload of x7 xdrive40d?

1. Retrieval: Tool Selection LLM Completion

1. Retrieval: Sqlite Tool SQLite Query

Query

SELECT payload FROM car_variant WHERE name = 'BMW X7 xDrive40d';

Result

payload

835

2. Retrieval: Tool Selection LLM Completion

2. Retrieval: Document Database Tool VectorDB Query

Query

What is the payload capacity of the BMW X7 xDrive40d?

Results

ID

http://iaais.fraunhofer.de/bmw/instance/variant/bmw-x7-xdrive40d

Title

bmw x7 xdrive40d

Content

bmw x7 xdrive40d is a Car. bmw x7 xdrive40d is a Product. bmw x7 xdrive40d is a Vehicle. bmw x7 xdrive40d has empty weight 2565 Kg. 2565 Kg is empty weight of bmw x7 xdrive40d. bmw x7 xdrive40d has fuel capacity 80 l. 80 l is fuel capacity of bmw x7 xdrive40d. bmw x7 xdrive40d has height 1.835 m. 1.835 m is height of bmw x7 xdrive40d. bmw x7 xdrive40d has identifier bmw x7 xdrive40d. bmw x7 xdrive40d is identifier of bmw x7 xdrive40d. bmw x7 xdrive40d has is variant of bmw x7. bmw x7 is variant of bmw x7 xdrive40d. bmw x7 xdrive40d has length 5.181 m. 5.181 m is length of bmw x7 xdrive40d. bmw x7 xdrive40d has luggage compartment volume 750 to 2120 l. 750 to 2120 l is luggage compartment volume of bmw x7 xdrive40d. bmw x7 xdrive40d has maximum weight 3325 Kg. 3325 Kg is maximum weight of bmw x7 xdrive40d. bmw x7 xdrive40d has name BMW X7 xDrive40d. BMW X7 xDrive40d is name of bmw x7 xdrive40d. **bmw x7 xdrive40d has payload 835 kg.** 835 kg is payload of bmw x7 xdrive40d. bmw x7 xdrive40d has price 104000.00 Euros. 104000.00 Euros is price of bmw x7 xdrive40d. bmw x7 xdrive40d has top speed 245 km/h. 245 km/h is top speed of bmw x7 xdrive40d. bmw x7 xdrive40d has vehicle engine bmw x7 xdrive40d. bmw x7 xdrive40d is vehicle engine of bmw x7 xdrive40d. bmw x7 xdrive40d has wheelbase 3.105 m. 3.105 m is wheelbase of bmw x7 xdrive40d. bmw x7 xdrive40d has width 2.218 m. 2.218 m is width of bmw x7 xdrive40d.

URL

Score

0.535

ID

http://iaais.fraunhofer.de/bmw/instance/variant/bmw-x7-xdrive40i

Title

bmw x7 xdrive40i

Content

bmw x7 xdrive40i is a Car. bmw x7 xdrive40i is a Product. bmw x7 xdrive40i is a Vehicle. bmw x7 xdrive40i has empty weight 2490 Kg. 2490 Kg is empty weight of bmw x7 xdrive40i. bmw x7 xdrive40i has fuel capacity 83 l. 83 l is fuel capacity of bmw x7 xdrive40i. bmw x7 xdrive40i has height 1.835 m. 1.835 m is height of bmw x7 xdrive40i. bmw x7 xdrive40i has identifier bmw x7 xdrive40i. bmw x7 xdrive40i is identifier of bmw x7 xdrive40i. bmw x7 xdrive40i has is variant of bmw x7. bmw x7 is variant of bmw x7 xdrive40i. bmw x7 xdrive40i has length 5.181 m. 5.181 m is length of bmw x7 xdrive40i. bmw x7 xdrive40i has luggage compartment volume 750 to 2120 l. 750 to 2120 l is luggage compartment volume of bmw x7 xdrive40i. bmw x7 xdrive40i has maximum weight 3215 Kg.

Example question 2: Math computations satisfied via SQL

Average price of x7 variants?

RAGONITE BMW ITERATIVE RETRIEVAL

+ New Chat

My Chats

payload of x7 x...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xDrive...

average price of the ...

average price of the i...

payload of x1 sDrive...

payloads of x3 cars?

top speed of x1 sDriv...

payload of x1 sDrive...

do you have payload ...

do you have payload ...

do you have info on t...

payload of x1

wheel colors for x5?

price of x7 cars with ...

height distribution of...

average price of x7 c...

What is the average ...

User

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Ragonite

The payload of the BMW X7 xDrive40d is 835 kg. [Source 1, Source 2]

User

average price of x7 variants?

Ragonite

The average price of BMW X7 variants is 102,000 euros. [Source 1]

User

cool features?

Ragonite

The BMW X7 boasts several cool features, including:

1. Comfort highlights like 6 seats, automatic climate control with 5-zone control, and a Bowers and Wilkins diamond surround sound system. [Source 2]

2. Innovative highlights such as the BMW Operating System 8, Comfort Access, and smartphone integration. [Source 2]

3. Interior design highlights with aesthetics and technology in the cockpit, glass application CraftedClarity, and a spacious and comfortable rear. [Source 2]

These features emphasize luxury, comfort, and technological innovation in the design of the BMW X7.

Ask Ragonite about BMW cars...

What is the power of the engine of BMW X1 models?

What electric cars does BMW have?

What power do they have?

Which of them produces the least amount of CO2?

0.667

2. Retrieval: Document Database Tool Lexical Search

3. Retrieval: Tool Selection LLM Completion

Answer Generation LLM Completion

average price of x7 variants?

1. Retrieval: Tool Selection LLM Completion

1. Retrieval: Sqlite Tool SQLite Query

Query

SELECT AVG(price) AS average_price FROM base_car WHERE name LIKE '%X7%';

Result

average_price

102000

2. Retrieval: Tool Selection LLM Completion

2. Retrieval: Document Database Tool VectorDB Query

2. Retrieval: Document Database Tool Lexical Search

3. Retrieval: Tool Selection LLM Completion

Answer Generation LLM Completion

cool features?

1. Retrieval: Tool Selection LLM Completion

1. Retrieval: Sqlite Tool SQLite Query

2. Retrieval: Tool Selection LLM Completion

2. Retrieval: Document Database Tool VectorDB Query

Example question 3: Informal intents satisfied via verbalizations

Cool features (of x7)?

RAGONITE BMW ITERATIVE RETRIEVAL

+ New Chat

My Chats

payload of x7 x...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xdrive...

payload of x7 xDrive...

average price of the ...

average price of the i...

payload of x1 sDrive...

payloads of x3 cars?

top speed of x1 sDriv...

payload of x1 sDrive...

do you have payload ...

do you have payload ...

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What power do they have?

Which of them produces the least amount of CO2?

ID

http://iais.fraunhofer.de/bmw/instance/bmw-x7

Title

bmw x7

Content

bmw x7 is a Car. bmw x7 is a Car Model. bmw x7 is a Product. bmw x7 is a Vehicle. bmw x7 has accessory 20 22 BMW light alloy wheel V spoke style 750 reflex silver 2C complete winter wheel. 20 22 BMW light alloy wheel V spoke style 750 reflex silver 2C complete winter wheel is accessory of bmw x7. bmw x7 has accessory 21 22 BMW light alloy wheel Y spoke style 752 Jet Black. 21 22 BMW light alloy wheel Y spoke style 752 Jet Black is accessory of bmw x7. bmw x7 has accessory BMW clothes hanger for travel 26 comfort system. BMW clothes hanger for travel 26 comfort system is accessory of bmw x7. bmw x7 has accessory BMW roof box 520 black 2Ftitanium silver. BMW roof box 520 black 2Ftitanium silver is accessory of bmw x7. bmw x7 has description The BMW X7 fascinates from the first encounter with its combination of superior power, luxurious comfort and expressive design language.. The BMW X7 fascinates from the first encounter with its combination of superior power, luxurious comfort and expressive design language. is description of bmw x7. bmw x7 has fuel type diesel. diesel is fuel type of bmw x7. bmw x7 has fuel type gasoline. gasoline is fuel type of bmw x7. bmw x7 has identifier bmw x7. bmw x7 is identifier of bmw x7. bmw x7 has innovative highlight Comfort highlight 3A 6 seats. Comfort highlight 3A 6 seats is innovative highlight of bmw x7. bmw x7 has innovative highlight Comfort highlight 3A Automatic climate control with 5 zone control. Comfort highlight 3A Automatic climate control with 5 zone control is innovative highlight of bmw x7. bmw x7 has innovative highlight Comfort highlight 3A Bowers and Wilkins diamond surround sound system. Comfort highlight 3A Bowers and Wilkins diamond surround sound system is innovative highlight of bmw x7. bmw x7 has innovative highlight Innovative highlight 3A BMW operating system 8. Innovative highlight 3A BMW operating system 8 is innovative highlight of bmw x7. bmw x7 has innovative highlight Innovative highlight 3A Comfort access. Innovative highlight 3A Comfort access is innovative highlight of bmw x7. bmw x7 has innovative highlight Innovative highlight 3A Smartphone integration. Innovative highlight 3A Smartphone integration is innovative highlight of bmw x7. bmw x7 has innovative highlight Interior design highlight 3A Aesthetics and technology in the cockpit. Interior design highlight 3A Aesthetics and technology in the cockpit is innovative highlight of bmw x7. bmw x7 has innovative highlight Interior design highlight 3A Glass application CraftedClarity. Interior design highlight 3A Glass application CraftedClarity is innovative highlight of bmw x7. bmw x7 has innovative highlight Interior design highlight 3A Spacious and comfortable rear. Interior design highlight 3A Spacious and comfortable rear is innovative highlight of bmw x7. bmw x7 has name BMW X7. BMW X7 is name of bmw x7. bmw x7 has price 102000.00 Euros. 102000.00 Euros is price of bmw x7. bmw x7 has standard equipment Acoustic glazing. Acoustic glazing is standard equipment of bmw x7. bmw x7 has standard equipment Adaptive 2 axle air suspension. Adaptive 2 axle air suspension is standard equipment of bmw x7. bmw x7 has standard equipment Adaptive LED headlights incl. high beam assistant and LED taillights. Adaptive LED headlights incl. high beam assistant and LED taillights is standard equipment of bmw x7. bmw x7 has standard equipment Ambient interior lighting incl. ambient light strip. Ambient interior lighting incl. ambient light strip is standard equipment of bmw x7. bmw x7 has standard equipment Automatic climate control with 4 zone control. Automatic climate control with 4 zone control is standard equipment of bmw x7. bmw x7 has standard equipment Automatic operation for two part tailgate. Automatic operation for two part tailgate is standard equipment of bmw x7. bmw x7 has standard equipment BMW Live Cockpit Professional with BMW Curved Display and BMW Head Up Display. BMW Live Cockpit Professional with BMW Curved Display and BMW Head Up Display is standard equipment of bmw x7. bmw x7 has standard equipment BMW Operating System 8 with navigation. BMW Operating System 8 with navigation is standard equipment of bmw x7. bmw x7 has standard equipment Comfort access. Comfort access is standard equipment of bmw x7. bmw x7 has standard equipment Comfort seats with electric seat adjustment and memory 2C front. Comfort seats with electric seat adjustment and memory 2C front is standard equipment of bmw x7. bmw x7 has standard equipment Connected Package Professional. Connected Package Professional is standard equipment of bmw x7. bmw x7 has standard equipment Cruise control with brake function. Cruise control with brake function is standard equipment of bmw x7. bmw x7 has standard equipment Driving Assistant. Driving Assistant is standard equipment of bmw x7. bmw x7 has standard equipment Folding rear seat back 2C 40 3A20 3A40 divisible. Folding rear seat back 2C 40 3A20 3A40 divisible is standard equipment of bmw x7. bmw x7 has standard equipment Illuminated door sill trims. Illuminated door sill trims is standard equipment of bmw x7. bmw x7 has standard equipment Light alloy wheels. Light alloy wheels is standard equipment of bmw x7. bmw x7 has standard equipment Panorama glass roof. Panorama glass roof is standard equipment of bmw x7. bmw x7 has standard equipment Parking Assistant incl. Active Park Distance Control 2C rear view camera and rear view assistant. Parking Assistant incl. Active Park Distance Control 2C rear view camera and rear view assistant is standard equipment of bmw x7. bmw x7 has standard equipment Personal eSIM. Personal eSIM is standard equipment of bmw x7. bmw x7 has standard equipment Satin aluminum roof rails. Satin aluminum roof rails is standard equipment of bmw x7. bmw x7 has standard equipment Seat upholstery in BMW Individual extended leather Merino incl. seat heating for driver and front passenger. Seat upholstery in BMW Individual extended leather Merino incl. seat heating for driver and front passenger is standard equipment of bmw x7. bmw x7 has standard equipment Sports leather steering wheel. Sports leather steering wheel is standard equipment of bmw x7. bmw x7 has standard equipment Steptronic Sport transmission. Steptronic Sport transmission is standard equipment of bmw x7. bmw x7 has standard equipment Upper part of instrument panel in Sensafin. Upper part of instrument panel in Sensafin is standard equipment of bmw x7. bmw x7 has vehicle model date 2022. 2022 is vehicle model date of bmw x7.

ID

http://iais.fraunhofer.de/bmw/instance/variant/engine/bmw-x7-xdrive40i

Title

bmw x7 xdrive40i

Content

bmw x7 xdrive40i is a Engine Specification. bmw x7 xdrive40i has acceleration time 5.8 s. 5.8 s is acceleration time of bmw x7 xdrive40i. bmw x7 xdrive40i has