

ReSCORE: Label-free Iterative Retriever Training for Multi-hop Question Answering with Relevance-Consistency Supervision

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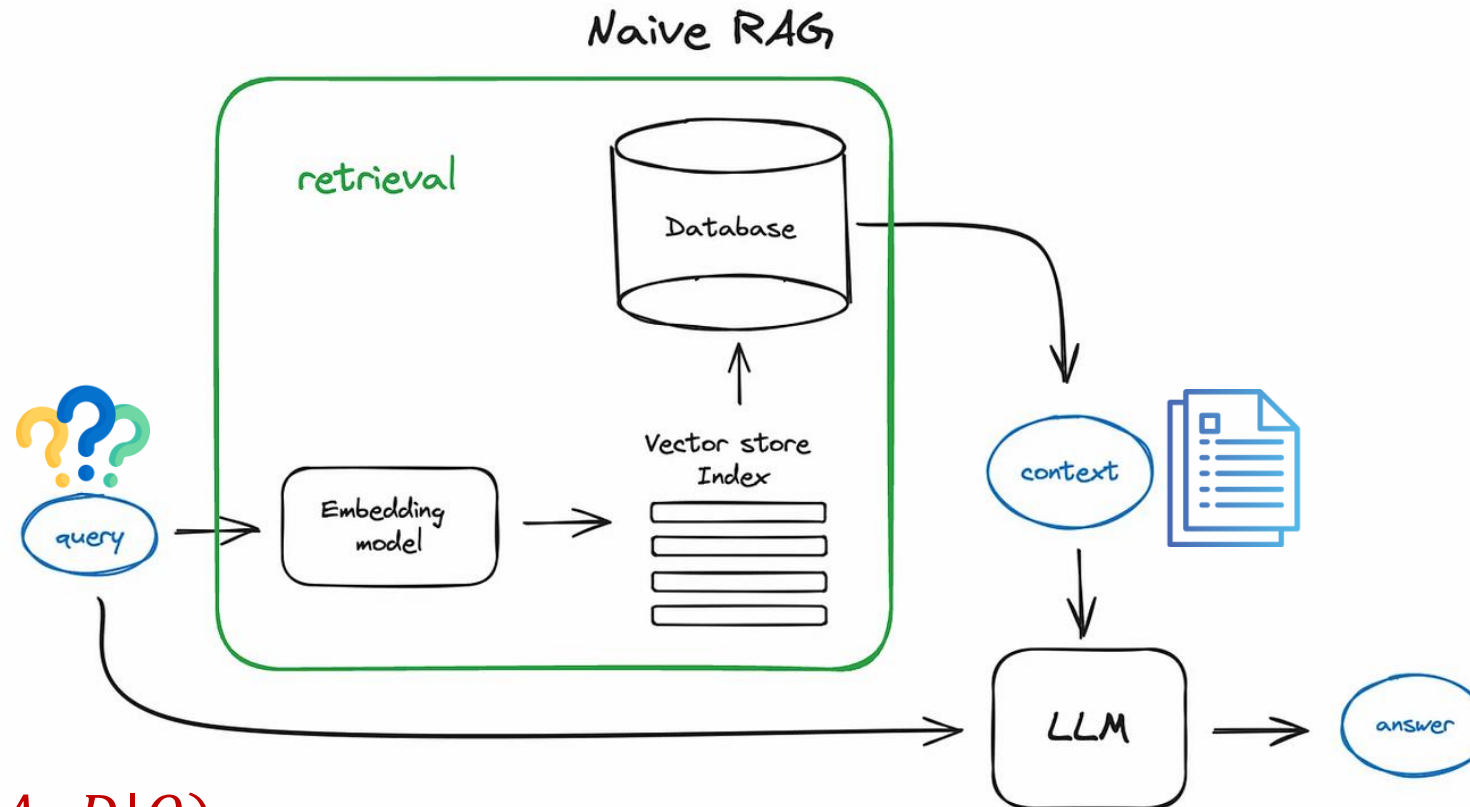


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Multimodal Interactive
Intelligence Laboratory

Retrieval Augmented Generation

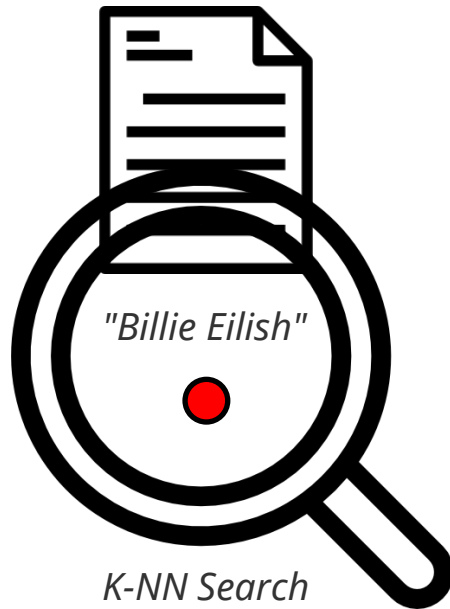


$$P_{QA}(A|Q) = \sum_D P(A, D|Q)$$

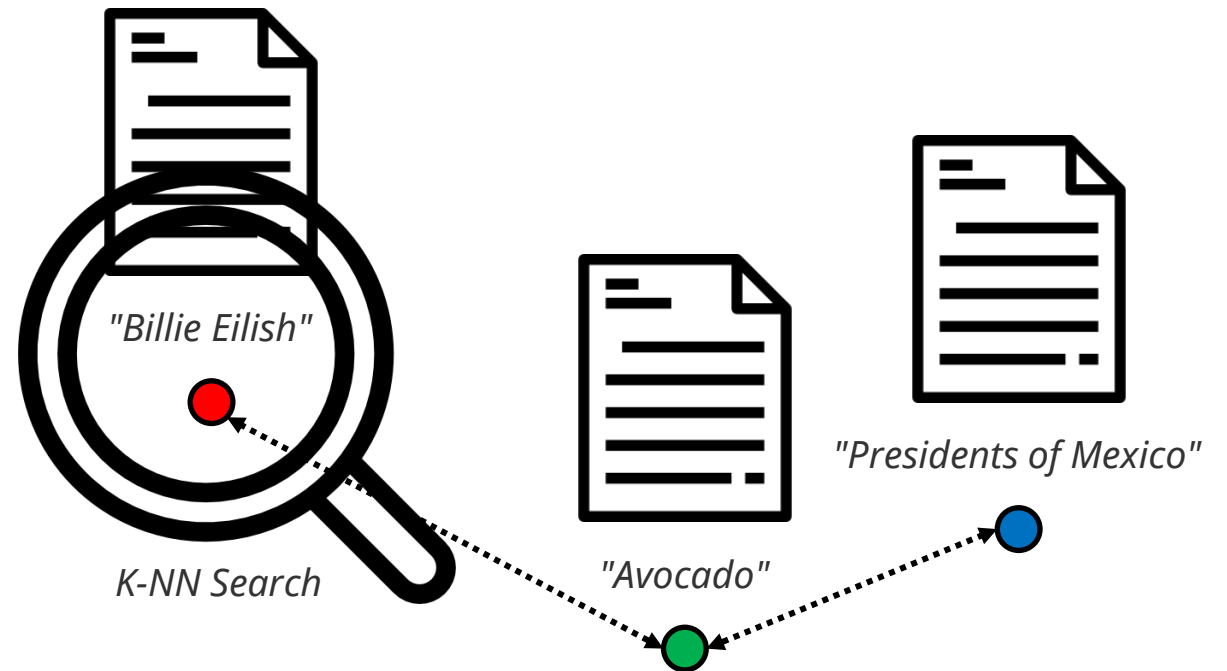
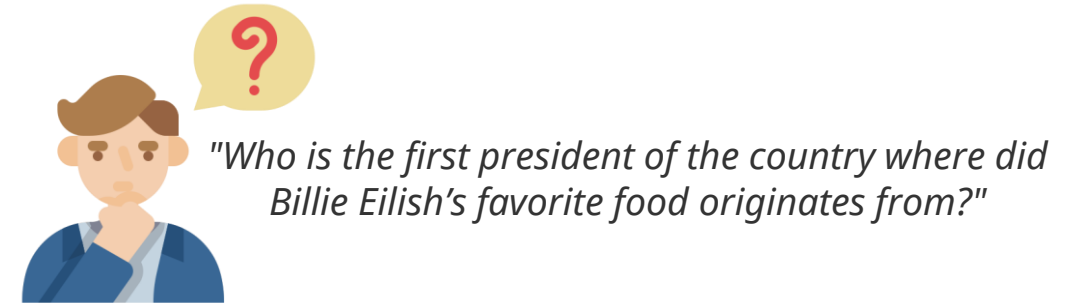
$$P_{RAG}(A, D|Q) = P_{generate}(A|D, Q) P_{retrieve}(D|Q)$$

Multi-hop Question Answering & Challenges

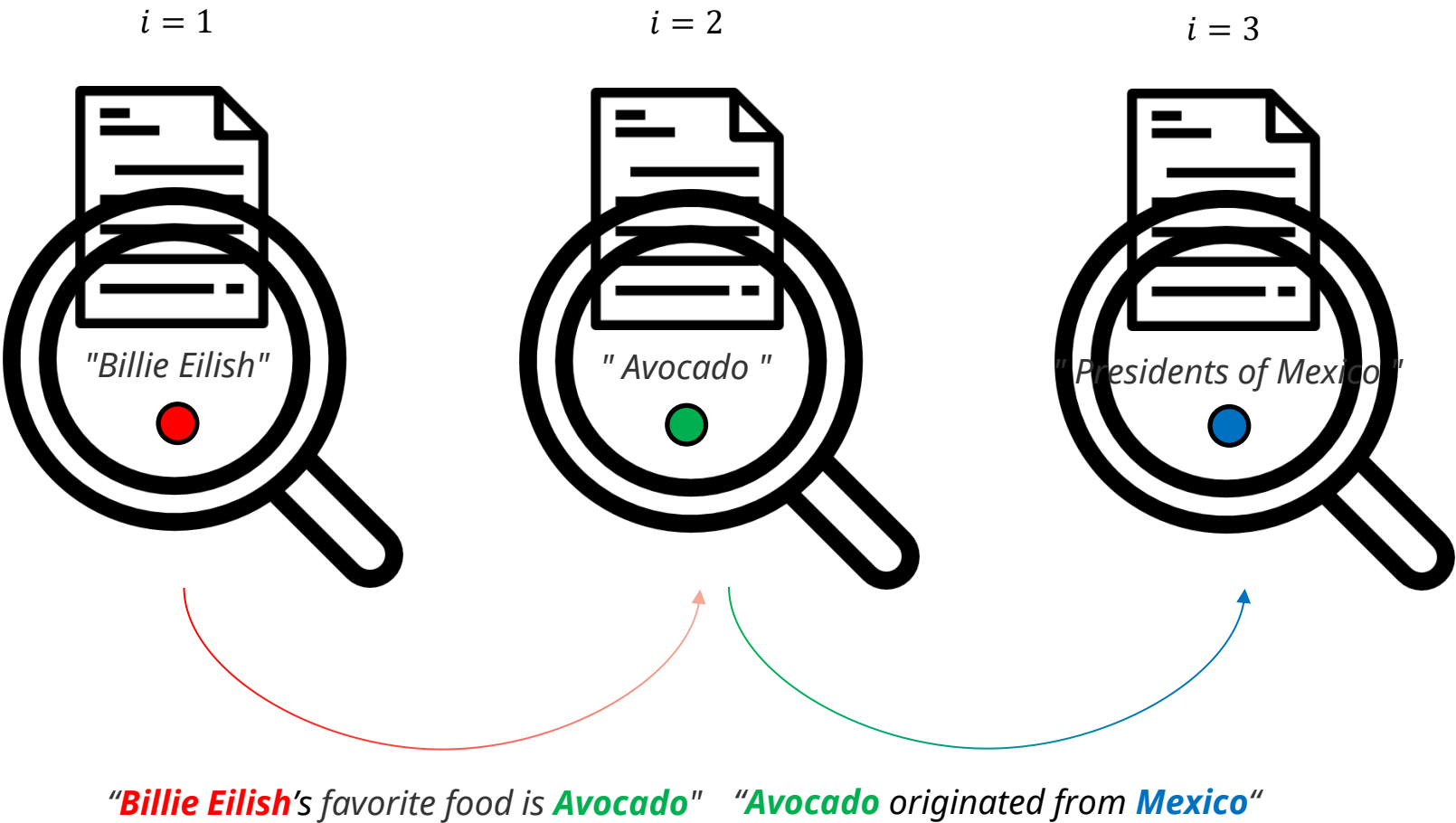
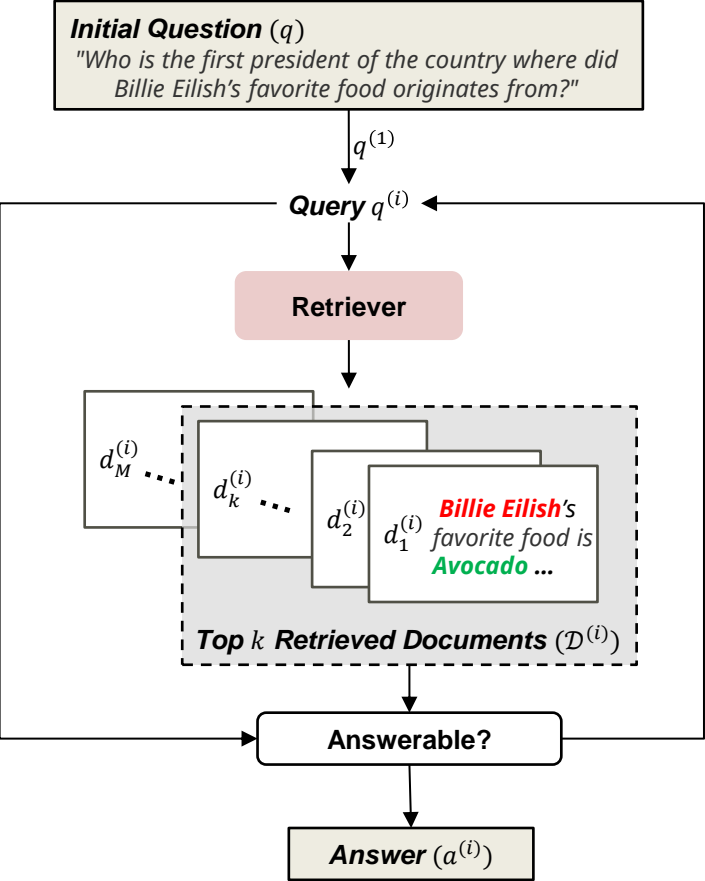
Single-hop



Multi-hop



Iterative RAG Inference Framework



Challenges of Labeling MHQA & Label-free Training



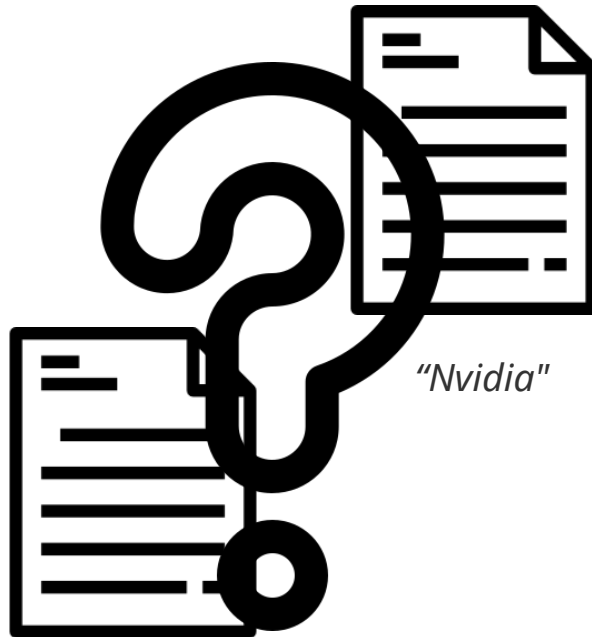
"Who is the first president of the country where did Billie Eilish's favorite food originates from?"



"Billie Eilish"



"Elon Musk"



"South Korea"



"Nvidia"



"Presidents of Mexico"



"Avocado"



"Paris"

Relevance-Consistency Supervision

$$P_{QA}(A|Q) = \sum_D P(A, D|Q)$$

$$P_{RAG}(A, D|Q) = P_{generate}(A|D, Q) P_{retrieve}(D|Q)$$

$$P_{Retriever}(D|Q) \propto P_{LLM}(A, Q|D)$$

$$P_{LLM}(A, Q|D) = P_{consistency}(A|D, Q) P_{relevance}(Q|D)$$



"Who is the first president of the country where did Billie Eilish's favorite food originates from?"



"Presidents of Mexico"

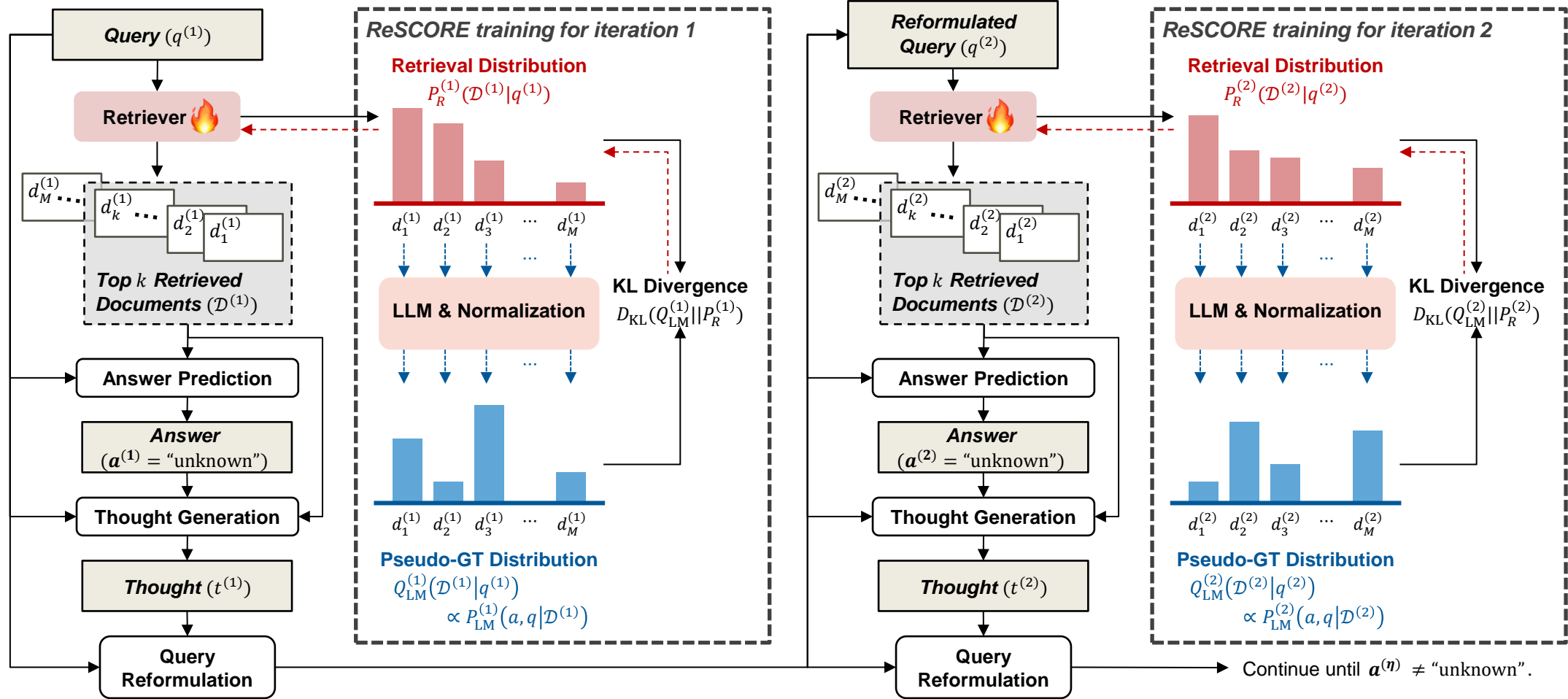
$P_{consistency}(A|D, Q)$



"Billie Eilish"

$P_{relevance}(Q|D)$

ReSCORE Training



Comparison to SOTA MHQA Baselines

Model	MuSiQue		HotpotQA		2WikiMHQA	
	EM	F1	EM	F1	EM	F1
ReAcT (GPT-3.5+BM25) [†]	10.2	19.7	36.0	46.9	28.0	37.3
FLARE (GPT-3.5+BM25) [†]	11.2	18.7	36.4	47.8	31.8	42.8
Self-RAG (GPT-3.5+BM25) [†]	10.6	19.2	33.8	44.4	24.4	30.8
Adaptive-Note (GPT-3.5+BM25) [†]	13.2	24.2	45.6	58.4	43.2	54.2
IRCoT (Flan-T5-XL+BM25) [‡]	22.0	31.8	44.42	56.2	49.7	54.9
Adaptive-RAG (Flan-T5-XL+BM25) ^{‡‡}	23.6	31.8	42.0	53.8	40.6	49.8
Our Baseline (Llama-3.1-8B+BM25)	15.2	23.6	42.2	55.7	44.6	52.2
Our Baseline (Llama-3.1-8B+Contriever)	15.2	23.8	39.4	52.3	32.8	41.6
IQATR (Llama-3.1-8B+Contriever trained w/ ReSCORE)	<u>23.4</u>	32.7	47.2	59.3	50.0	59.7

	MuSiQue			HotpotQA			2WikiMHQA		
	cEM	EM	F1	cEM	EM	F1	cEM	EM	F1
Self-Ask	-	13.8	27.0	-	-	-	-	30.0	36.1
Self-Ask + SE	-	15.2	27.2	-	-	-	-	40.1	52.6
SearChain + ColBERT	17.1	-	-	56.9	-	-	46.3	-	-
IQATR (Ours)	30.4	23.4	32.7	59.6	47.2	59.3	57.0	50.0	59.7

Model	QA		MHR _i @8		
	EM	F1	$i = 1$	$i = 2$	$i = \eta_n$
MuSiQue					
Self-RAG*	1.2	8.2	25.8	25.8	25.8
+ReSCORE	2.8	10.8	24.9	31.6	31.6
FLARE	7.3	13.3	31.0	37.1	37.1
+ReSCORE	8.2	15.3	30.9	40.1	43.3
Adaptive-Note	9.6	17.7	44.9	50.2	50.2
+ReSCORE	11.2	20.5	45.1	49.8	55.3
Our Baseline	15.2	23.8	44.9	51.6	51.6
+ReSCORE	23.4	32.7	46.8	63.0	65.2
HotpotQA					
Self-RAG*	5.6	17.9	36.1	36.5	36.5
+ReSCORE	8.7	19.2	33.8	37.2	37.2
FLARE	27.5	38.9	37.2	48.4	48.4
+ReSCORE	31.4	42.5	39.2	48.5	51.7
Adaptive-Note	42.0	55.3	44.8	49.8	50.1
+ReSCORE	43.8	58.0	47.3	63.3	77.2
Our Baseline	39.4	52.3	44.8	47.5	47.5
+ReSCORE	47.2	59.3	46.6	69.3	72.4
2WikiMHQA					
Self-RAG*	3.0	19.1	26.3	27.1	27.1
+ReSCORE	5.6	21.2	25.9	28.4	32.8
FLARE	23.2	35.0	32.5	42.9	42.9
+ReSCORE	26.5	38.0	33.2	45.6	45.6
Adaptive-Note	35.7	46.1	45.7	59.2	59.2
+ReSCORE	37.4	49.3	49.8	63.2	67.5
Our Baseline	32.8	41.6	45.7	56.9	56.9
+ReSCORE	50.0	59.7	51.2	81.2	88.0

Pseudo-GT Supervision Ablation

Method	MuSiQue			HotpotQA			2WikiMHQA		
	R@8	EM	F1	R@8	EM	F1	R@8	EM	F1
None	47.1	15.2	23.8	61.7	39.4	52.3	58.9	32.8	41.6
$P_{LM}(a d, q)$	41.4	5.8	12.3	42.8	19.2	26.4	41.9	18.8	26.5
$P_{LM}(q d)$	47.9	15.9	25.9	65.9	42.0	53.9	63.2	39.2	47.9
$P_{LM}(q, a d)$	55.7	16.4	26.3	68.3	43.6	56.4	67.1	41.4	51.7

$$P_{QA}(A|Q) = \sum_D P(A, D|Q)$$

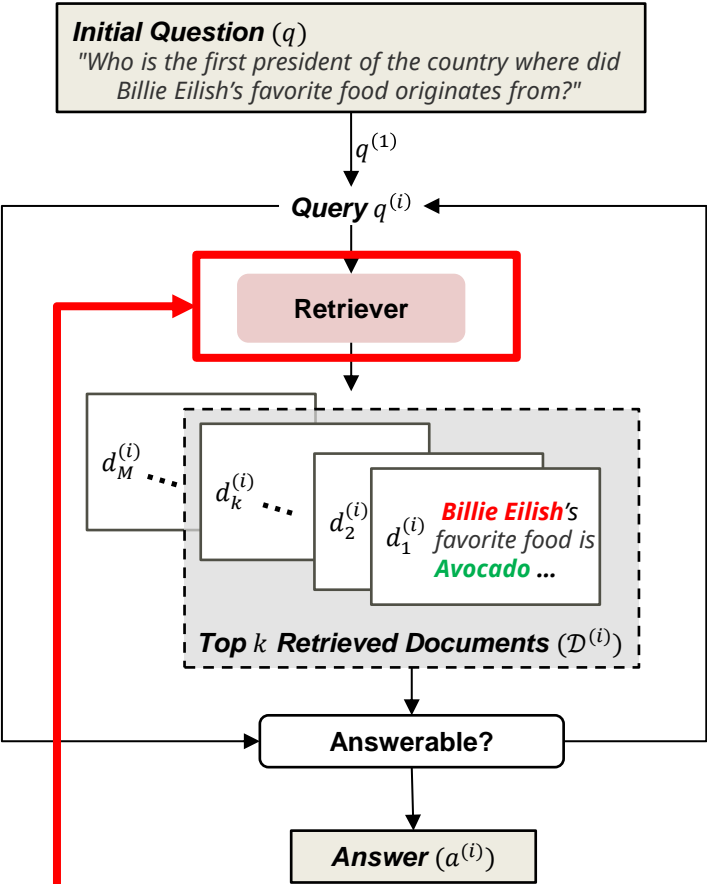
$$P_{RAG}(A, D|Q) = P_{generate}(A|D, Q) P_{retrieve}(D|Q)$$

$$P_{Retriever}(D|Q) \propto P_{LLM}(A, Q|D)$$

$$P_{LLM}(A, Q|D) = P_{Consistency}(A|D, Q) P_{Relevance}(Q|D)$$

Pseudo-GT Label	R@2	R@4	R@8	R@16
MuSiQue				
None	32.7	40.1	47.1	53.6
$P_{LM}(q d)$	34.6	41.1	47.9	54.2
$P_{LM}(a q, d)$	28.9	35.1	41.4	47.8
$P_{LM}(q, a d)$	42.7	50.3	55.7	60.4
HotpotQA				
None	49.4	56.5	61.7	66.3
$P_{LM}(q d)$	55.2	62.4	65.9	69.1
$P_{LM}(a q, d)$	27.5	34.4	42.8	52.5
$P_{LM}(q, a d)$	58.1	64.6	68.3	70.7
2WikiMHQA				
None	46.4	54.3	58.9	63.4
$P_{LM}(q d)$	50.8	59.1	63.2	66.1
$P_{LM}(a q, d)$	26.1	33.3	41.9	51.2
$P_{LM}(q, a d)$	53.7	63.0	67.1	68.7

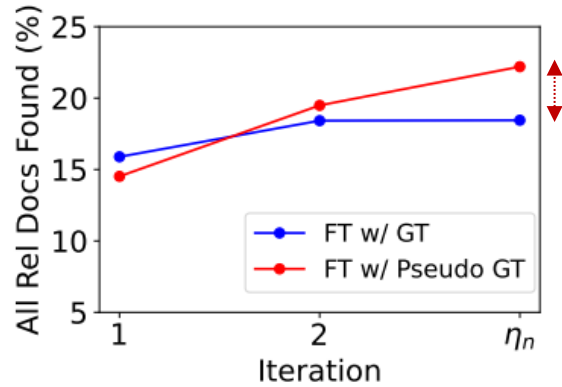
Comparison with GT



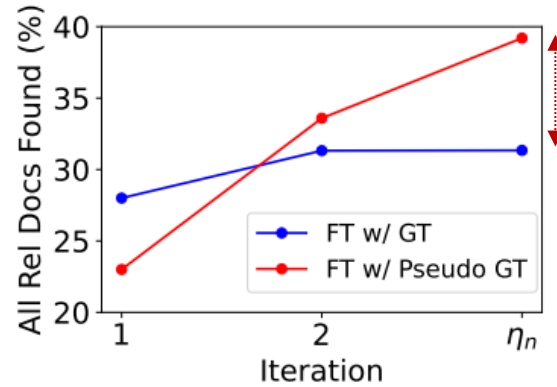
Replaced the **Retriever** with GT-trained

Label	QA		MHR _i @8		
	EM	F1	<i>i</i> = 1	<i>i</i> = 2	<i>i</i> = η_n
MuSiQue					
None	15.2	23.8	44.9	51.6	51.6
GT	15.8	24.9	46.7	54.8	54.8
Pseudo-GT	23.4	32.7	46.8	63.0	65.2
HotpotQA					
None	39.4	52.3	44.8	47.5	47.5
GT	45.2	55.8	48.7	52.7	52.7
Pseudo-GT	47.2	59.3	46.6	69.3	72.4
2WikiMHQA					
None	32.8	41.6	45.7	56.9	56.9
GT	37.1	46.2	48.5	61.7	61.7
Pseudo-GT	50.0	59.7	51.2	81.2	88.0

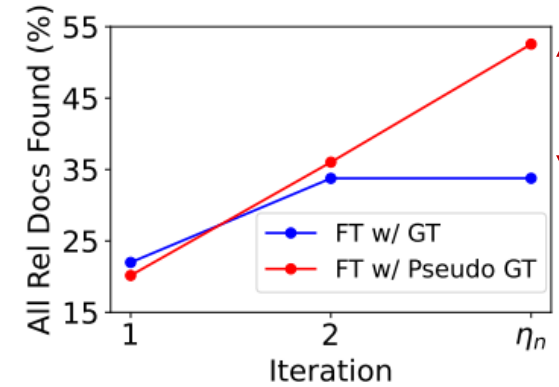
Comparison of GT and Pseudo-GT Labels



(a) MuSiQue Dataset

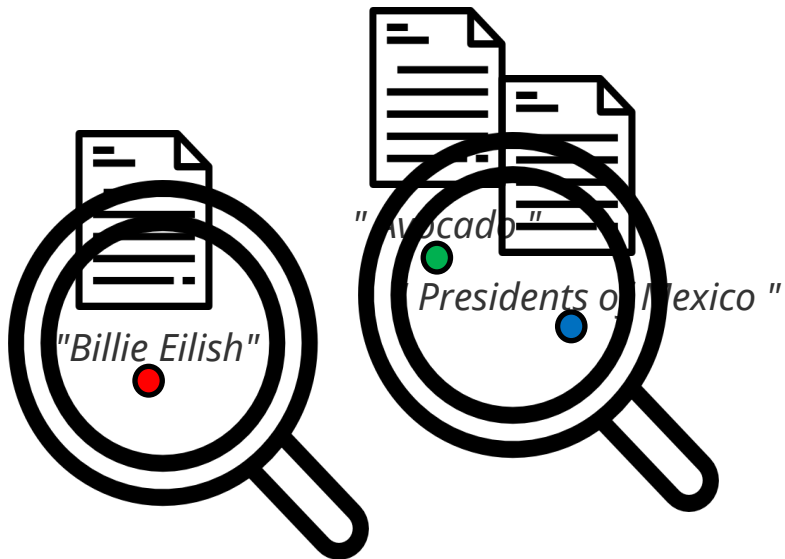


(b) HotpotQA Dataset

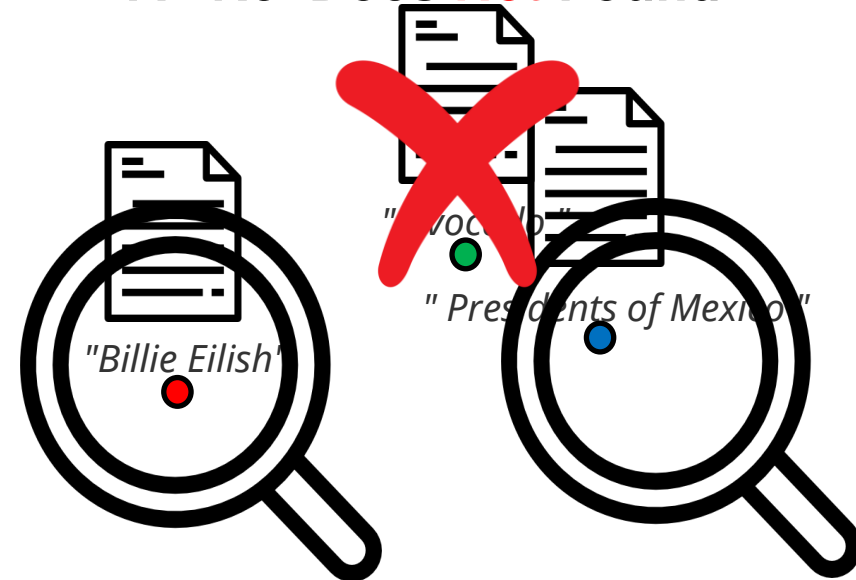


(c) 2WikiMHQA Dataset

All Rel Docs Found



All Rel Docs **Not** Found



Query Reformulation Ablation



Query Reformulation

None

"Who is the first president of the country where did Billie Eilish's favorite food originates from?"

OR

LLM-rewrite

"Who is the first president of the country where did **Avocado** originates from?"

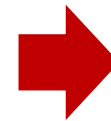
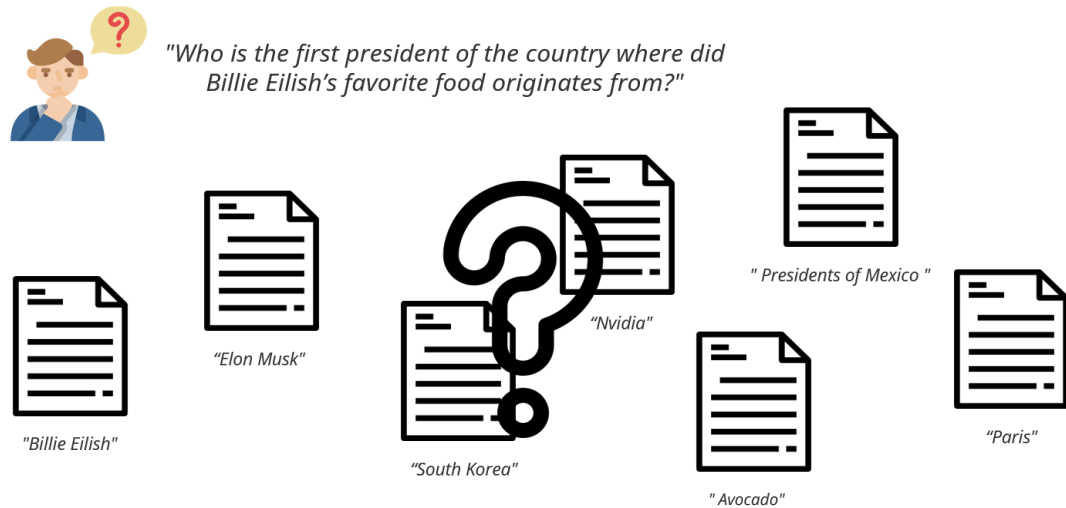
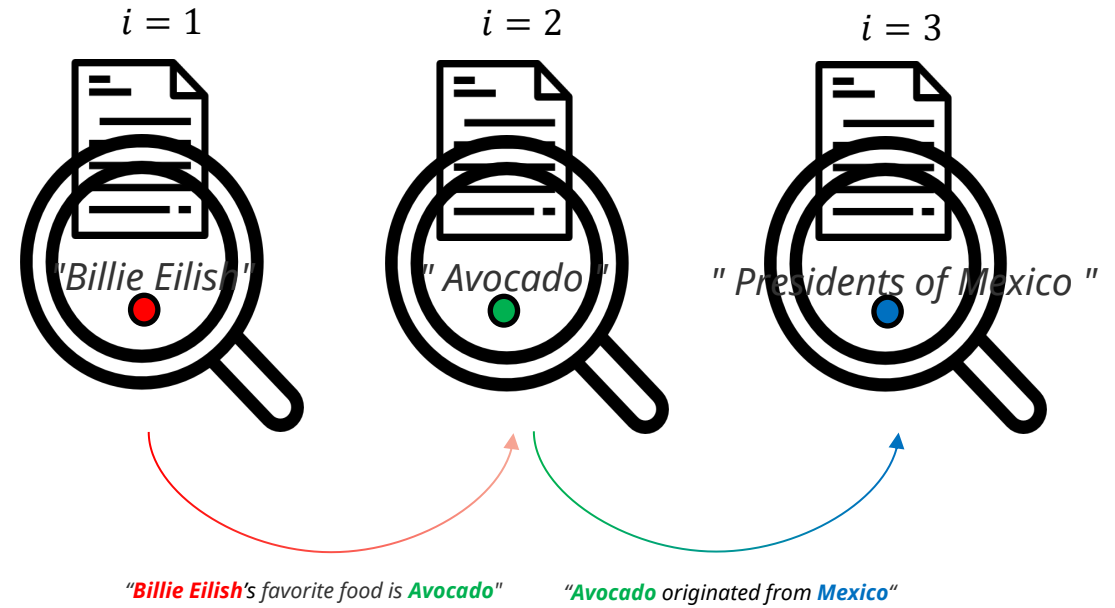
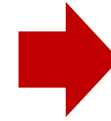
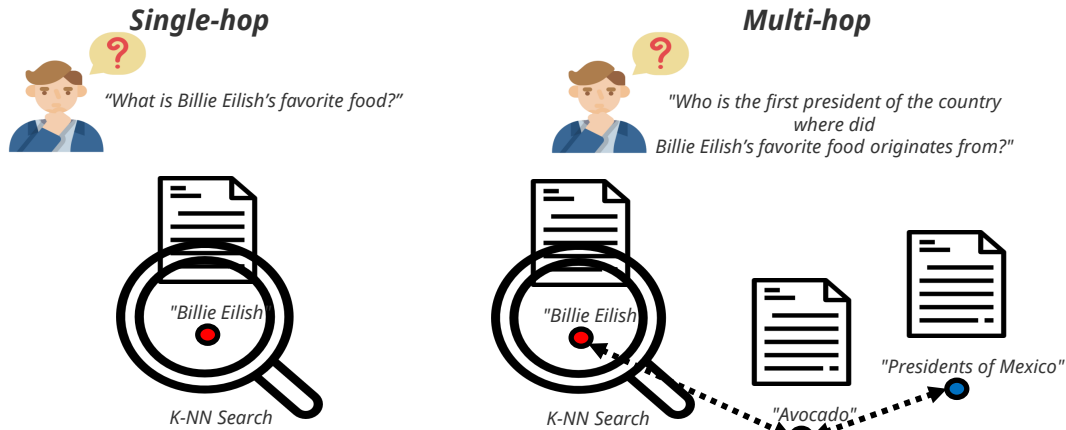
OR

Thought-concat

"Who is the first president of the country where did Billie Eilish's favorite food originates from? **Billie Eilish's** favorite food is **Avocado**."

Reformulation Method	QA		MHR _i @8		
	EM	F1	$i = 1$	$i = 2$	$i = \eta_n$
MuSiQue					
None	10.8	17.8	44.7	45.4	47.4
LLM-rewrite	21.2	30.5	45.1	56.7	63.7
Thought-concat	23.4	32.7	46.8	63.0	65.2
HotpotQA					
None	29.4	41.1	42.8	43.6	43.8
LLM-rewrite	44.2	57.4	41.9	54.8	64.7
Thought-concat	47.2	59.3	46.6	69.3	72.4
2WikiMHQA					
None	35.6	44.7	48.6	49.7	49.8
LLM-rewrite	51.7	60.1	50.0	86.0	89.5
Thought-concat	50.0	59.7	51.2	81.2	88.0

Summary



$$P_{QA}(A|Q) = \sum_D P(A, D|Q)$$

$$P_{RAG}(A, D|Q) = P_{generate}(A|D, Q) P_{retrieve}(D|Q)$$

$$P_{Retriever}(D|Q) \propto P_{LLM}(A, Q|D)$$

$$P_{LLM}(A, Q|D) = P_{Consistency}(A|D, Q) P_{Relevance}(Q|D)$$

E.O.D.