

A Data Construction

A.1 Full list of datasets.

For coverage of a wide range of data sources, we collected instances from four categories of knowledge-intensive scenarios: (1) Fact Checking includes FEVER (Thorne et al. 2018). (2) Dialogue includes Wizard of Wikipedia (Dinan et al. 2018) and QReCC (Anantha et al. 2021). (3) Open-domain Q&A includes Natural Questions (Kwiatkowski et al. 2019), HotpotQA (Yang et al. 2018), 2WikiMHQA (Ho et al. 2020), StrategyQA (Geva et al. 2021) and ASQA (Stelmakh et al. 2022). (4) Commonsense Reasoning includes ComsmosQA (Huang et al. 2019), ARC-Easy (Clark et al. 2018), OpenBookQA (Mihaylov et al. 2018) and ThoughtSource (Wei et al. 2022). In addition, we also sampled from some generic instruction datasets to ensure flexibility and creativity in our framework, including GPT-4 Alpaca (Peng et al. 2023), Alpaca³, OpenAssistant (Köpf et al.), FLAN-V2 (Longpre et al. 2023), and Dolly⁴. Table 5 shows the full list of training instances. The total dataset amount is 500k instances, where the long-trajectory subset includes 140k well-designed instances, and the short-trajectory subset contains 360k easily accessible instances.

A.2 Datasets Construction Details

We propose two distinct types of datasets: Long-trajectory Datasets and Short-trajectory Datasets, which apply in different stages of Long-short trajectory learning, respectively. These datasets differ in their structure, objectives, and the way they are used to train models, as shown in Table 5. By leveraging both types of datasets, we can develop robust and versatile framework that combine the benefits of task-specific training with the power of end-to-end reasoning.

Long-trajectory Datasets. We use the following steps to construct the long trajectory dataset.

Step1. As shown in Table 5, we leverage existing datasets and transform them into a unified format. Let $\mathcal{D} = (x_i, y_i)_{i=1}^N$ denote a QA dataset, where x_i represents the question and y_i represents the corresponding answer. For multi-turn dialogue datasets, we concatenate the historical context and the current question to form x_i , and use the answer from the last turn as y_i . This allows us to standardize both single-turn datasets and multi-turn dialogue datasets into a consistent format of (x_i, y_i) pairs.

Step2. To generate the Long-trajectory Datasets, we employ GPT-4 and an off-the-shelf retriever. For each input x , we use few-shot prompting to generate multiple query texts (q_1, q_2, \dots, q_m) , where the number of queries m is determined by GPT-4. The prompting strategies are tailored to different types of datasets, including Fact Verification, Multi-turn Dialogue, Open-domain Q&A, Commonsense Reasoning, and etc.

Step3. For each query text q_j ($j = 1, 2, \dots, m$), we retrieve k candidate passages from a fixed knowledge base

(e.g., Wikipedia), resulting in a total of $m \times k$ candidate passages.

Step4. We utilize few-shot prompting with GPT-4 to determine the relevance of each candidate passage in answering the user’s question. Specifically, for each passage, GPT-4 is prompted to identify the specific facts (multiple sentences in the the passage) that can help answer the question, or output “irrelevant” if the passage does not contain relevant information. We require that the facts outputted by GPT-4 must be contained within the passage.

Step5. The final answer consists of the original answer and the passage number of the facts supporting the answer. The Long-trajectory Datasets are constructed by combining the reconstructed queries, retrieved passages, located facts, and generated answer into a single sequence. For each (x, y) pair, we transform y into a long-trajectory reasoning process as follows:

```
Input : x
-----
Output :
<Reconstructor> q1, q2, ... </eor>
<retrieval>
[1] xxxxxxxx
[2] xxxxxxxx
[3] xxxxxxxx
...
</retrieval>
<Locator>
[Relevant]:[1] xxxx
[Irrelevant]:[2] Lacking Supporting Facts.
[Irrelevant]:[3] Lacking Supporting Facts.
...
</eol>
<Generator> y [Cite]: [1]</eog>
```

By reconstructing the original answer y_i into a long-trajectory reasoning process, we explicitly model the steps of query rewriting, retrieval, fact locating, and question answering. This approach allows us to create datasets that showcase the complex reasoning capabilities required for knowledge-intensive tasks, providing valuable insights and resources for advancing research in this area. The loss function is computed only for the components generated by the large language model, i.e., the `<Reconstructor>`, `<Locator>`, and `<Generator>` sections, while the `<retrieval>` section is excluded from the loss computation.

Short-trajectory Dataset. In contrast to the Long-trajectory Datasets, the Short-trajectory Datasets focus on the individual characteristics of each agent. These datasets are constructed to target specific skills, such as intent reconstruction, fact location, and response generation, and can be used for pre-training models or training specialized agents. This property allows such dataset to be obtained directly from existing open source datasets, as shown in Table 5.

For intent reconstruction. The construction of Short-trajectory Datasets follows the same approach as Long-trajectory Datasets. These datasets can be formalized as:

```
Input : x
```

³https://github.com/tatsu-lab/stanford_alpaca

⁴[https://huggingface.co/datasets/databricks/databricks-dolly-](https://huggingface.co/datasets/databricks/databricks-dolly-15k)

Category	Dataset Name	Long-Trajectory	Short-Trajectory			
			Locator	Intent	Response	
					w/o \mathcal{F}	w/ \mathcal{F}
Fact Verification	FEVER	22,485	25,211	10,761	1,757	3,513
Dialogue	QReCC	18,363	-	21,000	3,383	-
	WoW	10,701	-	-	3,824	-
Open-domain Q&A	Natural Questions	17,770	25,065	15,069	1,347	2,695
	HotpotQA	10,792	25,325	10,200	1,356	2,714
	2WikiMHQA	9,847	25,118	17,140	1,675	3,348
	StrategyQA	2,281	-	-	-	-
	ASQA	4,236	-	-	667	1,335
Commonsense Reasoning	CosmosQA	6,923	6,315	-	-	2,526
	OpenbookQA	4,923	-	-	495	992
	Arc-Easy	2,242	-	-	-	-
	ThoughtSource	5,918	-	20,000	18,711	-
General	Alpaca-GPT4	13,944	-	-	26,001	-
	Alpaca-Stanford	12,082	-	-	25,989	-
	FLAN-V2	-	-	-	30,316	-
	Dolly	-	-	-	6,802	-
	OpenAssistant	-	-	-	19,141	-
Total		142,507	107,034	94,170	141,464	17,123

Table 5: Distribution of our dataset. w/o \mathcal{F} indicates that response generator without facts guidance, w/ \mathcal{F} on the contrary

<Reconstructor>

Output: q1, q2, ... </eor>

where q_i represents the reconstructed knowledge query intent from the user input x .

For fact location. We can leverage existing datasets such as HotpotQA, Natural Questions, and 2WikiMHQA. Fact location does not require the output from the reconstructor, instead, it only needs the user input and the retrieved passages. These datasets can be formalized as:

Input: x
 <retrieval>
 [1] xxxxxxxx
 [2] xxxxxxxx
 [3] xxxxxxxx
 </retrieval>
 <Locator>

Output:
 [Relevant]:[1] xxxx
 [Irrelevant]:[2] Lacking Supporting Facts.
 [Irrelevant]:[3] Lacking Supporting Facts.
 <eol>

For response generation. We construct two types of training samples, one type that directly generates an answer based on the user question:

Input: x
 <Generator>

Output: y </eog>

Another is that answers the question based on both the question and the located facts:

Input: x
 <Locator>
 [Relevant]:[1] xxxx
 [Irrelevant]:[2] Lacking Supporting Facts.
 [Irrelevant]:[3] Lacking Supporting Facts.
 </eol>
 <Generator>

Output: y [Cite]: [1] </eog>

The Short-trajectory Datasets offer several advantages. First, they do not necessarily require a complete long-trajectory training dataset, allowing us to utilize a large number of existing NLP datasets. Second, they enable focused training on individual skills, and subsequent short trajectories do not need to depend on the outputs of all previous short trajectories. By pre-training LLMs on cost-effective Short-trajectory Datasets, we can reduce the amount of cost-ineffective Long-trajectory training data required to achieve better performance comparable to LLMs without pre-training.

Furthermore, the Short-trajectory Datasets can be used to train specialized agents, each responsible for a specific task (e.g., intent reconstruction, fact location, or response generation). These agents can then be combined to form a complete

question-answering system, offering a modular and adaptable approach to solving complex tasks.

A.3 Datasets example

Table 7 shows two training cases in the long-trajectory subset and Table 8 shows the four training cases in the short-trajectory subset.

B Experimental Setups

B.1 Dataset and Evaluation Metrics

- **Fact verification:** PubHealth (Akhtar, Cocarascu, and Simperl 2022) is a fact verification dataset about public health. We use accuracy as an evaluation metric and report on the test set, which contains 987 test examples with veracity labels (true, false).
- **Multiple-choice reasoning:** ARC-Challenge (Clark et al. 2018) is a multiple-choice questions dataset about science exams, containing 1172 test examples. We also use accuracy as an evaluation metric.
- **Open-domain question answering:** 1) PopQA (Mallen et al. 2022) is a long-tailed set of 1,399 rare entity queries collected from Wikipedia. 2) SQuAD 1.1 (Rajpurkar et al. 2016) contains 8,886 queries that is created through a process where annotators write questions based on the documents they read. Following previous practice (Asai et al. 2023; Gao et al. 2023), we assessed this track accuracy by matching, *i.e.*, ground truth appears in the model responses.
- **Ambiguous question answering:** ASQA (Gao et al. 2023) contains 4132 ambiguous factoid questions of the long-form response. Following the official setting (Gao et al. 2023), we use Mauve to assess fluency, and Str_EM and Rouge-L (R-L) to assess accuracy.

B.2 Baselines

Knowledge internalization methods: LLMs internalize a great deal of world knowledge in their parameters, so generic LLMs are regarded as Knowledge internalization methods. In training and inference, we use the official system prompt or instruction format. knowledge internalization methods are as follows:

- Instruct fine-tuned and preference alignment models: ChatGPT⁵ (Ouyang et al. 2022), Llama-2-Chat-7B (Touvron et al. 2023), Llama-2-Chat-13B (Touvron et al. 2023).
- Instruct fine-tuned models: Instruct-v0.2-7B (Jiang et al. 2023), Vicuna-v1.5-13B (Zheng et al.), and Alpaca2-7B (Following Alpaca⁶, we trained based on Llama-2).

Knowledge enhancement methods: We employ widely used knowledge augmentation methods. Since some of the methods do not provide model weights, we replicated them using the same base model and data as ours. In addition, we also use the same retrieval model and knowledge base as

⁵We use gpt-3.5-turbo-0125.

⁶https://github.com/tatsu-lab/stanford_alpaca

Dataset	Instruction
ARC-C	Given four answer candidates, choose the best answer choice.
PubHealth	Is the following statement correct or not? Say true if it’s correct; otherwise, say false.
ASQA	Answer the following question. The question may be ambiguous and have multiple correct answers, and in that case, you have to provide a long-form answer including all correct answers.

Table 6: Instructions for zero-shot evaluations.

ours for fairness. Knowledge enhancement methods are as follows:

- **REPLUG** (Shi et al. 2023) treats the frozen black-box LLM and augments it with a tuneable retrieval model. We use Llama-2-Chat-7B (Touvron et al. 2023) as black-box LLM.
- **VANILLA-7B** (Gao et al. 2023) is a framework that retrieves passages, then instructs the model to distinguish relevant documents and cite accordingly. We use Llama-2-Chat-7B as the backbone.
- **INTERACT-7B** (Gao et al. 2023) is an interactive prompting scheme that allows the agent to check passages by executing the "Check" "Output" and "End" actions. We use Llama-2-Chat-7B as the backbone.
- **RAIT-7B** (Lin et al. 2023) retrofit LLMs with retrieval capabilities by tuning. To be fair, we train pre-trained Llama-2 using the same dataset as ours.
- **SelfRAG-7B** (Asai et al. 2023) is a framework to enhance the response quality through retrieval on demand and self-reflection. SelfRAG uses an end-to-end optimization strategy.
- **MMAgent-3*7B** is our setting modular multi-agent framework. We train separate agents based on the same dataset and complete the workflow by decoupling them. We use same pre-trained Llama-2 as backbone to train three independent agents.

B.3 Setting Details

Training Detail. We use pre-trained LLM, Llama2-7B (Touvron et al. 2023), as our initial model. We use 8*V100 GPUs with 32GB memory to conduct our Short-Long Trajectory learning by LoRA method (Hu et al. 2021). Both short and long-trajectory learning are conducted over 2 epochs with a total batch size of 128, a peak learning rate of 2e-4, and 3% warmup steps, followed by linear decay. The maximum token length is set to 3,076 for short-trajectory learning and 2,816 for long-trajectory learning. Multi-GPU distributed training is performed using DeepSpeed Stage 3 (Rasley et al. 2020).

Evaluation Details. Knowledge Retriever is driven by Retriever-MSMARCO (Izacard et al. 2021) and access top-3 knowledge documents from the official Wikipedia corpus

Algorithm 1: Inference

Require: Intent Reconstructor \mathcal{A}_i , Knowledge Retriever \mathcal{A}_r , Fact Locator \mathcal{A}_l , and Response Generator \mathcal{A}_g , Passage collections $d_1, \dots, d_{k \times m}$, trajectory head token h , trajectory end token e

Input: user prompt x

Output: y

```
1:  $\mathcal{A}_i$  predicts  $q_1, \dots, q_m, e_i, h_r$  given  $x, h_i$ 
2: for each  $p$  in  $q_1, \dots, q_m$  do
3:   Retrieve passages  $d_1, \dots, d_k$  using  $\mathcal{A}_r$  given  $p$ , top- $k$ 
4: end for
5:  $q = \{d_1, \dots, d_{k \cdot m}\}$ 
6:  $\mathcal{A}_l$  predicts  $\{(r_1, f_1), \dots, (r_{k \cdot m}, f_{k \cdot m})\}, e_l, h_g$  given  $x, \{d_1, \dots, d_{k \cdot m}\}, e_r, h_l$ 
7: if  $r = [\text{Relevant}]$  then
8:    $\mathcal{A}_g$  predicts  $y, e_g$  given  $\{(r_1, f_1), \dots, (r_{k \cdot m}, f_{k \cdot m})\}, e_l, h_g$ 
9: else
10:   $\mathcal{A}_g$  predicts  $y, e_g$  given  $x, h_g$ 
11: end if
```

(Karpukhin et al. 2020). These documents are segmented into non-overlapping fragments of 100 words. In the evaluation, we conduct zero-shot assessment, *i.e.*, and we provide instructions describing tasks without few-shot demonstrations (Asai et al. 2023). Greedy decoding was used across the evaluations.

Evaluation Task Instructions. Following the existing work (Asai et al. 2023), in addition to open-domain Q&A, we implemented zero-shot evaluations by providing prompts for task descriptions as shown in Table 6.

C Inference

Inference Overview. Algorithm 1 gives an inference overview of our multi-agent framework. The systematic procedure is delineated in the following steps: \mathcal{A}_i first mines the explicit intent $\bar{q} = \{q_1, q_2, \dots, q_m\}$ from the instruction x . Next, \mathcal{A}_r retrieves top- k knowledge documents $\bar{d} = \{d_1, d_2, \dots, d_{k \times m}\}$ using each intent. Then, \mathcal{A}_l determines each relevant knowledge passage and further locates the fact span $f \subset d_{k \times m}$. Finally, \mathcal{A}_g utilizes the previous execution trajectory to generate response y and citations when facts exist, otherwise \mathcal{A}_g utilizes only x .

D Case Study

To present the performance generated by the proposed SMART, we conduct case studies on ARC-Challenge (Clark et al. 2018), ASQA (Gao et al. 2023) and PubHealt (Akhtar, Cocarascu, and Simperl 2022) datasets. In the short-form generation, as shown in Figure 5, the Intent Reconstructor clarifies the instruction of multiple-choice reasoning into formally and semantically clear knowledge intent. Figure 6 shows that the Fact Locator can correctly evaluate Document 3 as [Irrelevant], which is prone to misidentification. In the long-form generation, as shown in Figure 7, we can observe that Response Generator generates a more fluent in-

struction response even compared to Ground Truth. Overall, our multi-agent framework can effectively solve different types of knowledge-intensive tasks through reconstructing knowledge intent, accessing external knowledge, discriminating relevant information to identify factual spans, and ultimately crafting informed responses. This process enhances the knowledge interpretability and response factuality, which demonstrates the effectiveness and advancement of our framework.

<Instruction> when was alice through the looking glass filmed? (from nq)

<Reconstructor> Search(Key figures in the War of 1812)</eor>

<retrieval>[1] War of 1812 -War of 1812 The War of 1812 was a conflict fought between the United States, the United Kingdom, and their respective allies from June 1812 to February 1815. Historians in Britain often see it as a minor theater of the Napoleonic Wars; in the United States and Canada, it is seen as a war in its own right, though it was separate. From the outbreak of war with Napoleonic France, Britain had enforced a naval blockade to choke off neutral trade to France, which the US contested as illegal under international law. To man the blockade, Britain impressed American merchant

[2] War of 1812 -to the United States. Some British officers and Canadians objected to handing back Prairie du Chien and especially Mackinac under the terms of the Treaty of Ghent. However, the Americans retained the captured post at Fort Malden, near Amherstburg, until the British complied with the treaty. Fighting between Americans, the Sauk, and other indigenous tribes continued through 1817, well after the war ended in the east. In 1812, Britain's Royal Navy was the world's largest, with over 600 cruisers in commission and some smaller vessels. Although most of these were involved in blockading the French navy and protecting British trade

[3] War of 1812 -War of 1812", sees the British as having fought to a much stronger position than the United States. Even tied down by ongoing wars with Napoleonic France, the British had enough capable officers, well-trained men, and equipment to easily defeat a series of American invasions of Canada. In fact, in the opening salvos of the war, the American forces invading Upper Canada were pushed so far back that they ended up surrendering Michigan Territory. The difference between the two navies was even greater. While the Americans famously (shockingly for contemporaries on both sides of the Atlantic) bested British ships in

</retrieval>

<Locator> [Relevant]: [1] War of 1812 -The War of 1812 was a conflict fought between the United States, the United Kingdom, and their respective allies from June 1812 to February 1815.

[Relevant]: [2] War of 1812 -Fighting between Americans, the Sauk, and other indigenous tribes continued through 1817, well after the war ended in the east.

[Relevant]: [3] War of 1812 -War of 1812", sees the British as having fought to a much stronger position than the United States.</eol>

<Generator> the United States , the United Kingdom , and their respective allies

[Cite]: [1] [2] [3]</eog>

<Instruction> Lichens are symbiotic organisms made of green algae and fungi. What do the green algae supply to the fungi in this symbiotic relationship? -A: carbon dioxide -B: food -C: protection -D: water</eoi> (from openbook)

<Reconstructor> Search(Symbiotic relationship between lichens -What do green algae supply to fungi in a lichen symbiotic relationship)</eor>

</retrieval> [1] Symbiosis in lichens -a very different form (morphology), physiology, and biochemistry than any of the constituent species growing separately. The algae or cyanobacteria benefit their fungal partner by producing organic carbon compounds through photosynthesis. In return, the fungal partner benefits the algae or cyanobacteria by protecting them from the environment by its filaments, which also gather moisture and nutrients from the environment, and (usually) provide an anchor to it. The majority of the lichens contain eukaryotic autotrophs belonging to the Chlorophyta (green algae) or to the Xanthophyta (yellow-green algae). About 90% of all known lichens have a green alga as a symbiont. Among

[2]

[3] Cyanobacteria -"Chara", where they may fix nitrogen. Cyanobacteria such as "Anabaena" (a symbiont of the aquatic fern "Azolla"), can provide rice plantations with biofertilizer. Many cyanobacteria form motile filaments of cells, called hormogonia, that travel away from the main biomass to bud and form new colonies elsewhere. The cells in a hormogonium are often thinner than in the vegetative state, and the cells on either end of the motile chain may be tapered. To break away from the parent colony, a hormogonium often must tear apart a weaker cell in a filament, called a necridium. Each individual cell (each single cyanobacterium)</retrieval>

<Locator>

[Relevant]:[1] Symbiosis in lichens -The algae or cyanobacteria benefit their fungal partner by producing organic carbon compounds through photosynthesis.

[Relevant]: [2] Algae -In these symbioses, the algae supply photosynthates (organic substances) to the host organism providing protection to the algal cells. The host organism derives some or all of its energy requirements from the algae.

[Irrelevant]: [3] Lacking Supporting Facts.</eol>

<Generator> B: food

[Cite]: [1] [2]</eog>

Table 7: Training examples of the long-trajectory subset.

<p><Instruction> What did Rahul Bose do in 1993? -Rahul Bose starred in the 1993 Are There Tigers in the Congo. What was Rahul Bose's early career? -Bose started his acting career on the Mumbai stage in Rahul D'Cunha's Topsy Turvey and Are There Tigers In The Congo? What other films has Rahul Bose starred in besides Topsy Turvey and Are There Tigers In The Congo? -D'Cunha's aunt was the casting director for director Dev Benegal's film English, August and suggested that Rahul Bose should play the lead role. What else has Rahul Bose done in his career besides Topsy Turvey, Are There Tigers in The Congo and English, August? -After English, August, Rahul Bose found work in television What was the name of the show Rahul Bose found work in after English, August? -Rahul Bose was offered a role in India's first English-language television serial, A Mouthful of Sky -What other TV series has Rahul Bose starred in besides A Mouthful of Sky? -Rahul Bose also co-hosted BBC World's Style! with Laila Rouass. When was Rahul Bose on BBC besides BBC World's Style! with Laila Rouass? -In 1997, Bose was cast to play the role of Saleem Sinai in the BBC adaptation of Salman Rushdie's novel Midnight's Children. What did he do in 2003?</eoi></p> <p><Reconstructor> (from Intent Reconstructor: qrec)</p> <p>Search(Current status of Grey's Anatomy TV show)</eor></p>	
<p><Instruction> Name three biometrics technologies.</eoi></p> <p><Generator> (from Response Generator: alpaca)</p> <p>1) Fingerprint recognition: This is a technology that identifies individuals by analyzing their unique fingerprint patterns. 2) Face recognition: This is a biometric technology that analyzes the facial features of an individual in order to identify or verify their identity. 3) Retinal scanning: This is a biometric technology that uses the unique pattern of blood vessels in an individual's retina in order to identify them.</eog></p>	
<p><Instruction> Which film was released more recently, Kora Terry or Yi Yi?</eoi></p> <p><Locator> -[Irrelevant]: [1] Lacking Supporting Facts -[Relevant]: [2] Kora Terry -Kora Terry is a 1940 German drama film directed by Georg Jacoby and starring Marika Röck, Will Quadflieg and Josef Sieber. -[Irrelevant]: [3] Lacking Supporting Facts -[Irrelevant]: [4] Lacking Supporting Facts -[Irrelevant]: [5] Lacking Supporting Facts -[Relevant]: [6] Yi Yi-Yi Yi is a 2000 Taiwanese drama film written and directed by Edward Yang.</eol></p> <p><Generator> (from Response Generator: wikimultihop)</p> <p>Yi Yi</p> <p>[Cite]: [2] [6]</eog></p>	
<p><Instruction> What is the name of this English musician, comedian, and actor, who narrated Dream Street?</eoi></p> <p><retrieval>[1] Dream Street (UK TV series) -Dream Street is a British children's television series that ran from 6 May 1999 to 2002 on "CITV". The show is narrated by British comedian Russ Abbot, and was aimed at children aged from 2 to 7. The show featured talking toy vehicles, which were radio controlled in real time. The series aired back on CITV around 2008. -[2] Dream Street (UK TV series) -Dream Street is a British children's television series that ran from 6 May 1999 to 2002 on "CITV". The show is narrated by British comedian Russ Abbot, and was aimed at children aged from 2 to 7. The show featured talking toy vehicles, which were radio controlled in real time. The series aired back on CITV around 2008. -[3] Russ Abbot -Russ Abbot (born Russell A. Roberts; 18 September 1947) is an English musician, comedian and actor. He first came to public notice during the 1970s as the singer and drummer with British comedy showband the "Black Abbots", along with Leonard 'Lenny' Reynolds, later forging a prominent solo career as a television comedian with his own weekly show on British television. -[4] Dream Street (Janet Jackson album) -nDream Street is the second studio album by American musician Janet Jackson, released on October 23, 1984, by A&M Records. More pop than her debut album's "bubblegum soul" feel, the album wasn't the runaway success that Janet's father Joseph thought it would be, peaking at number one hundred forty-seven on the "Billboard" 200 in 1984. The album did have one modest hit for Jackson, the top ten R&B single, "Don't Stand Another Chance", produced by brother Marlon. Also, the video for the song "Dream Street", her first music video, was shot during the shooting of the TV show "Fame".</retrieval></p> <p><Locator> (from Fact Loctor: wikimultihop)</p> <p>[Relevant]: [1] Dream Street (UK TV series) -Dream Street is a British children's television series that ran from 6 May 1999 to 2002 on "CITV". -[Relevant]: [2] Dream Street (UK TV series) -The show is narrated by British comedian Russ Abbot, and was aimed at children aged from 2 to 7. -[Relevant]: [3] Russ Abbot -Russ Abbot (born Russell A. Roberts; 18 September 1947) is an English musician, comedian and actor. -[Relevant]: [4] Lacking Supporting Facts </eol></p>	

Table 8: Training examples of the short-trajectory subset.

Prompt used in ChatGPT for fact locator.

Instruction: Given an {instruction type}, answer, and external knowledge passage, your job is to determine whether the passage is relevant to the question and can provide useful information for obtaining the answer. If the passage meets this requirement, respond with [Relevant] and extract useful spans from the passage. The extracted spans consist of complete sentences to make the extracted span understandable standalone.

Question: Who won the 2016 ncaa football national championship?

Answer: The 2015 - 2016 season's ncaa national football championship game was played between the Clemson Tigers and the Alabama Crimson Tide on January 11, 2016. The Alabama Crimson Tide won the game by holding off the undefeated Clemson Tigers 45–40 in the fourth quarter.

Passage: The 2016 College Football Playoff National Championship was a bowl game that determined a national champion of NCAA Division I FBS college football for the 2015 season. It was played at University of Phoenix Stadium in Glendale, Arizona on January 11, 2016, and was the culminating game of the 2015–16 bowl season. The game was played between the winners of two pre-designated semifinal bowls played on December 31, 2015: the No. 1 Clemson Tigers, who beat the No. 4 Oklahoma Sooners 37–17 at the Orange Bowl, coached by Dabo Swinney in his 8th season, and the No. 2 Alabama Crimson Tide, who shut out the No. 3 Michigan State Spartans 38–0 at the

Rating: [Relevant]

Extracted span: It was played at University of Phoenix Stadium in Glendale, Arizona on January 11, 2016, and was the culminating game of the 2015–16 bowl season.

Question: Where was three billboards outside ebbing missouri film?

Answer: Principal filming for Three Billboards Outside Ebbing, Missouri was in Sylva, North Carolina. The actual billboards for the film were put in a pasture near Black Mountain, North Carolina, and the billboard scenes were filmed there because that location was better.

Passage: actual sign appeared in the film. The musical score was written by Carter Burwell, who had also supplied the score for McDonagh's films "In Bruges" and "Seven Psychopaths". As well as Burwell's score, the film features songs by ABBA, Joan Baez, The Felice Brothers, the Four Tops, Monsters of Folk, and Townes Van Zandt. "Three Billboards Outside Ebbing, Missouri" premiered in competition at the 74th Venice International Film Festival on September 4, 2017. It also had screenings at the 2017 Toronto International Film Festival, the 2017 San Sebastián International Film Festival (where it won the Audience Award), the BFI London

Rating: [Irrelevant]

Extracted span: None

Question: {input}

Answer: {output}

Passage: {text}

Rating:

Table 9: Prompt examples used in ChatGPT for fact locator of long-trajectory subset.

Prompt used in ChatGPT for WikiMHQA.

Instruction: Given a question, provide knowledge search intent to help better retrieve the answer from external document on the web (e.g., Wikipedia). Split the intent with ';' and write an explanation.

Question: Which magazine was started first Arthur's Magazine or First for Women?

Search Intent: Arthur's Magazine publication year; First for Women publication year

Explanation: By splitting the search into two parts, each focusing on the foundation date of the respective magazines. This approach allows for a direct comparison of their start dates to determine which magazine was started first.

Question: What is the legal age of marriage, without parental consent or other authorization, in Nebraska?

Search Intent: legal age of marriage in Nebraska without parental consent

Explanation: This intent directly targets the core of the question, ensuring that the search results will specifically address the legal stipulations surrounding marriage age in Nebraska, making it easier to provide a precise answer.

Question: Californian rock band Lit recorded A Place in the Sun in 1995, but what's their best known song?

Search Intent: Californian rock band Lit's most famous and popular songs

Explanation: The search focuses on identifying the most popular or well-recognized song by the Californian rock band Lit. This does not require information about the album A Place in the Sun or its recording date, but rather seeks to find which song by Lit is generally considered their biggest hit or most iconic track.

Question: {input}

Search Intent:

Table 10: Prompt examples used in ChatGPT for intent reconstructor of long-trajectory subset.

Prompt used in ChatGPT for Alpaca-GPT4.

Instruction: Given an instruction, provide clarified knowledge search intent to help better retrieve the answer from external document on the web (e.g., Wikipedia). If there are different intents, split them with ';'.

Instruction: Write a response that appropriately completes the request.\n\n Instruction:\n Name some nations with a monarchy government.

Search Intent: nations with a monarchy government

Explanation: The search focuses on nations with a monarchy government.

Instruction: Tell me two advantages of using AI assistants.?

Search Intent: Advantages of Artificial Intelligence Assistants

Explanation: The question "Tell me two advantages of using AI assistants?" has a search intent focused on understanding the benefits of AI assistants. The query seeks to identify two specific advantages of using AI assistants.

Instruction: Task: Come up with 5 example datasets that demonstrate the use of natural language processing.\n <|Input| >: <No input>

Search Intent: natural language processing example dataset

Explanation: the instruction asks for 5 example datasets that demonstrate the use of natural language processing (NLP). To determine the search intent, you need to identify the core elements of the question, which are "natural language processing" and "example datasets."

Instruction: {input}

Search Intent:

Table 11: Prompt examples used in ChatGPT for intent reconstructor of long-trajectory subset.

Prompt used in ChatGPT for WoW.

Instruction: Given a question, answer and chat history separated by new lines, provide a knowledge search intent for the question to help better obtain answers from external documents on the web (e.g., Wikipedia). The intent needs to consider important and necessary contextual information from history so that it can be fully understood.

History: History: What can you tell me about Gary Cherone? \n Gary Francis Caine Cherone is an American rock singer and songwriter, known for his work as the lead vocalist of Extreme and for his short stint for Van Halen. \n Did Gary Cherone sing well? \n Yes, Gary Cherone is also known for his work as the lead vocalist of the Boston rock group Extreme. \n What significant fact can you tell me about Gary Cherone that you liked? \n I like that Gary Cherone remained in contact and on good terms with Van Halen. \n What did Gary Cherone do after Van Halen? \n After his departure from Van Halen, Gary Cherone returned to Boston and put together a new project, Tribe of Judah.

Question: Did they release any albums during that time frame?

Answer: After Gary Cherone, Eddie Van Halen recovered from his hip surgery in November 1999, and no official statements were made by Van Halen and no music was released.

Explanation: The search intent arises from the user's interest in Gary Cherone's activities after leaving Van Halen. Therefore, the question "Did they release any albums during that time frame?" is interpreted as the user wanting to know if Van Halen released any albums after Cherone's departure.

Search Intent: Any album released by Eddie Van Halen after Gary Cherone left

History: Where does Call of the Dead take place\n It takes place in a desolate area of the Siberian tundra next to the frozen ruins of a broken cargo ship and a old Soviet lighthouse.\n What is Call ForThe Dead's theme\n The players are once again are tasked with surviving the never-ending onslaught of the Zombie hordes, while also dealing with a new, dangerous threat.

Question: What is the genre?

Answer: The genre is crime, spy novel.

Search Intent: the genre of Call For The Dead

Explanation: Based on the history and the content of the question, the search intent is to determine the genre or category to which "Call For The Dead" belongs. The user is seeking to identify the specific classification of this work within entertainment or gaming.

History: {history}

Question: {input}

Answer: {output}

Search Intent:

Table 12: Prompt examples used in ChatGPT for intent reconstructor of long-trajectory subset.



User Instruction:

Given some answer candidates, choose the best answer choice.

Which aspect of modern life could most likely cause an epidemic to turn into a pandemic?

A: vaccination

B: transportation

C: communication

D: sanitation

**Intent Reconstructor:**

What factors can lead to a pandemic from an epidemic

**Knowledge Retriever:**

[1] Bioterrorism

York Times" report, the Gates Foundation predicted that a modern outbreak similar to the Spanish Influenza pandemic (which killed between 50 million and 100 million people) could end up killing more than 360 million people worldwide, even considering widespread availability of vaccines and other healthcare tools. The report cited increased globalization, rapid international air travel, and urbanization as increased reasons for concern. In a March 9, 2017 interview with CNBC, former U.S. Senator Joe Lieberman, who was co-chair of the bipartisan Blue Ribbon Study Panel on Biodefense, said a worldwide pandemic could end the lives of more people than a

[2] Pandemic

animals infect people, then moves through the stage where the virus begins to spread directly between people, and ends with a pandemic when infections from the new virus have spread worldwide and it will be out of control until we stop it. A disease or condition is not a pandemic merely because it is widespread or kills many people; it must also be infectious. For instance, cancer is responsible for many deaths but is not considered a pandemic because the disease is not infectious or contagious. In a virtual press conference in May 2009 on the influenza pandemic, Dr Keiji

[3] Globalization and disease

in disease prevention. His findings, in conjunction with other vaccines that followed, changed the way globalization affected the world. Modern modes of transportation allow more people and products to travel around the world at a faster pace; they also open the airways to the transcontinental movement of infectious disease vectors. One example is the West Nile Virus. It is believed that this disease reached the United States via "mosquitoes that crossed the ocean by riding in airplane wheel wells and arrived in New York City in 1999."

With the use of air travel, people are able to go to foreign

**Fact Locator:**

[Relevant]: [1] Bioterrorism

The report cited increased globalization, rapid international air travel, and urbanization as increased reasons for concern.

[Relevant]: [2] Pandemic

A disease or condition is not a pandemic merely because it is widespread or kills many people; it must also be infectious.

[Relevant]: [3] Globalization and disease

Modern modes of transportation allow more people and products to travel around the world at a faster pace; they also open the airways to the transcontinental movement of infectious disease vectors.

**Response Generator:**

B: transportation

[Cite]: [1] [2] [3]

Ground Truth : B: transportation

Figure 5: Example of our SMART output on ARC-Challenge

	User Instruction: Is the following statement correct or not? Say true if it's correct; otherwise say false. Roche's schizophrenia drug misses goal in two late-stage trials.
	Intent Reconstructor: Roche's schizophrenia drug misses goal in two late-stage trials.
	Knowledge Retriever: [1] Bitopertin 66% on placebo ($p < 0.05$, per-protocol population). In January 2014, Roche reported that bitopertin failed to meet its endpoints in two phase III trials assessing its efficacy in reducing negative symptoms of schizophrenia. Subsequently, in April 2014, Roche announced that it was discontinuing all of its phase III trials of bitopertin for schizophrenia except for one. Though Roche has largely ceased its studies of bitopertin for schizophrenia, it is also investigating the drug in the treatment of obsessive-compulsive disorder (OCD), and is continuing its development for this indication. As of August 2014, bitopertin is in phase II clinical trials for OCD. [2] Tamas Bartfai for 'heartburn', as a consultant to Roche, the catechol-O-methyltransferase inhibitor (Tasmar-tolcapone) used in Parkinson's Disease, the first benzodiazepine-antagonist (flunitrazepam) for treatment of benzodiazepine overdoses, and as a consultant to Novartis the sphingosine 1-phosphate agonist gilenya-fingolimod as the first oral multiple sclerosis drug. He has also worked on four current drug candidates that as of 2015, are in phase 2 and 3 clinical trials. One of the most promising ones is the amyloid A β antibody that the Banner Alzheimer's Institute, Roche and the U.S. government are testing in Colombia for prevention of Alzheimer's disease in a large cohort with a familial [3] LY-404,039 Eli Lilly and Company announced their decision to stop their ongoing clinical studies investigating LY-2140023 as a treatment for schizophrenia after their phase II study did not meet its primary endpoint. The company completed a phase II, randomized, double-blind, placebo- and active-controlled, parallel-group-assignment, dose-ranging, inpatient, multi-center clinical trial. Patients were randomized to receive 5, 20, 40, or 80 mg of LY-2140023, placebo, or olanzapine for 28 days. Results of the clinical trial indicated that neither LY-2140023 nor olanzapine were significantly more efficacious than the placebo as determined with PANSS total scores. Post hoc analyses indicated only a trend towards improvement with LY-2140023, while
	Fact Locator: [Relevant]: [1] Bitopertin In January 2014, Roche reported that bitopertin failed to meet its endpoints in two phase III trials assessing its efficacy in reducing negative symptoms of schizophrenia. [Irrelevant]: [2] Lacking Supporting Facts [Irrelevant]: [3] Lacking Supporting Facts
	Response Generator: True [Cite]: [1] [3]
Ground Truth : True	

Figure 6: Example of our SMART output on PubHealth



User Instruction:

Answer the following question. The question may be ambiguous and have multiple correct answers, and in that case, you have to provide a long-form answer including all correct answers.
Who plays the superintendent in doctor blake mysteries?

**Intent Reconstructor:**

Actor who plays the superintendent in Doctor Blake Mysteries

**Knowledge Retriever:**

[1] Alex Blake (Criminal Minds)

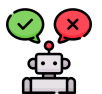
Alex Blake (Criminal Minds) Dr. Alex Blake (née Miller) is a fictional character on the CBS crime drama "Criminal Minds", portrayed by Jeanne Tripplehorn. Blake first appeared in "The Silencer" - episode one of season eight, replacing Agent Emily Prentiss who had resigned to go and run Interpol in "Run (Part II)". On May 14, 2014, it was revealed in the season 9 finale that Blake would be leaving the show. Tripplehorn's final episode as a main cast member on the show was on the May 14, 2014, episode "Demons". Blake's appointment at the BAU was met with some mixed

[2] The Doctor Blake Mysteries

The Doctor Blake Mysteries The Doctor Blake Mysteries is an Australian television series that premiered on ABC TV on 1 February 2013 at 8:30 pm. The series stars Craig McLachlan in the lead role of Doctor Lucien Blake, who returns home to Ballarat, northwest of Melbourne, in the late 1950s to take over his late father's general medical practice and role as police surgeon after an absence of 30 years. Five series aired as of 2017, with a telemovie scheduled to close the program at the completion of the fifth season. In October 2017, the Seven Network announced they acquired

[3] The Doctor Blake Mysteries

and is expected to include the regular characters of the present cast. The plots of four telemovies will see Doctor Lucien Blake disappear in mysterious circumstances, with his new bride Jean Beazley to take on a more central role. The Doctor Blake Mysteries The Doctor Blake Mysteries is an Australian television series that premiered on ABC TV on 1 February 2013 at 8:30 pm. The series stars Craig McLachlan in the lead role of Doctor Lucien Blake, who returns home to Ballarat, northwest of Melbourne, in the late 1950s to take over his late father's general medical practice and role as police surgeon.

**Fact Locator:**

[Irrelevant]: [1] Lacking Supporting Facts

[Relevant]: [2] The Doctor Blake Mysteries

The Doctor Blake Mysteries is an Australian television series that premiered on ABC TV on 1 February 2013 at 8:30 pm. The series stars Craig McLachlan in the lead role of Doctor Lucien Blake, who returns home to Ballarat, northwest of Melbourne, in the late 1950s to take over his late father's general medical practice and role as police surgeon after an absence of 30 years.

[Relevant]: [3] The Doctor Blake Mysteries

The series stars Craig McLachlan in the lead role of Doctor Lucien Blake, who returns home to Ballarat, northwest of Melbourne, in the late 1950s to take over his late father's general medical practice and role as police surgeon.

**Response Generator:**

The Doctor Blake Mysteries is an Australian television series that premiered on ABC TV on 1 February 2013 at 8:30 pm. The series stars Craig McLachlan in the lead role of Doctor Blake, who returns home to Ballarat, northwest of Melbourne, in the late 1950s to take over his late father's general medical practice and role as police surgeon after an absence of 30 years.

[Cite] : [2] [3]

Ground Truth : There were several superintendents in the TV series The Doctor Blake Mysteries. Actor Joel Tobeck played Chief Superintendent Matthew Lawson in Series 1-4.1 and 5. New Zealand actor Craig Hall played Chief Superintendent William Munro in Series 3 and 5. Australian actor Rodger Corser played Chief Superintendent Matthew Frank Carlyle in Series 4.

Figure 7: Example of our SMART output on ASQA