SYNC: A Synthetic Long-Context Understanding Benchmark for Controlled Comparisons of Model Capabilities

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Abstract

Recently, researchers have turned to synthetic tasks for evaluating long-context capabilities of large language models (LLMs) , as they offer more flexibility than realistic benchmarks in scaling both input length and dataset size. However, existing synthetic tasks typically target narrow skill sets such as retrieving information from massive input, limiting their ability to comprehensively assess model capabilities. Furthermore, existing benchmarks often pair each task with a different input context, creating confounding factors that prevent fair cross-task comparison. To address these limitations, we introduce SYNC, a new evaluation suite of synthetic tasks spanning domains including graph understanding and translation. Each domain includes three tasks designed to test a wide range of capabilities—from retrieval, to multi-hop tracking, and to global context understanding that that requires chain-of-thought (CoT) reasoning. Crucially, all tasks share the same context, enabling controlled comparisons of model performance. We evaluate 14 LLMs on SYNC and observe substantial performance drops on more challenging tasks, underscoring the benchmark's difficulty. Additional experiments highlight the necessity of CoT reasoning and demonstrate that SYNC poses a robust challenge for future models.

1 Introduction

Large language models (LLMs) have extended their context lengths with recent advances, enabling them to accommodate more diverse and extensive user inputs (OpenAI et al., 2024b; AI, 2024). To understand LLMs' capabilities when consuming long contexts, it is crucial to develop benchmarks with sufficiently long inputs. Early benchmarks for long-context evaluation primarily focus on realistic tasks, where data is either sourced from human-annotated documents (Pang et al., 2022) or existing text corpora (Shaham et al., 2023; Dong et al., 2024). While these tasks reflect real-world use cases, they are limited in flexibility: Once constructed, the input contexts in such datasets are essentially fixed, extending which to longer contexts often requires sourcing and annotating new data samples (Bai et al., 2024b; Wang et al., 2025). Precisely controlling the difficulty of understanding the contexts is also challenging, as they depend on the available realistic contexts. As a result, realistic benchmarks are not suitable for controlled evaluation of models' long-context capabilities.

Recently, synthetic benchmarks have emerged as a more scalable way to probe model capabilities at controllable lengths. A notable example is the needle-in-a-haystack (NIAH) test, where key-value pairs to be retrieved are inserted into long passages of irrelevant text (Kamradt, 2023). While such tests are simple to construct and offer extremely lengthy contexts without the need for human annotations, they only evaluate whether the model is able to pinpoint the required content. Although extensions of NIAH have been proposed to test other capabilities (Hsieh et al., 2024), the range of capabilities evaluated remains narrow. Moreover, existing synthetic benchmarks curate tasks with different input contexts which become confounding factors when comparing model performance across tasks to understand model behaviors.

To address these limitations of existing *synthetic* benchmarks, we propose a new benchmark, SYNC, comprising SYNthetic Contexts for fine-grained comparisons of LLMs' long-context capabilities.[1] SYNC features synthetic contexts covering two domains: *graph understanding* and *unseen language translation*. Three tasks are composed for each domain and designed to evaluate *a broader range of capabilities*, from simple information retrieval to multi-hop state tracking, and to global context un-

[1]Our data and data generation code are available at `https://shuyangcao.github.io/projects/sync/`.

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derstanding that requires synthesizing and reasoning across multiple pieces of information scattered throughout the long context.

For example, in graph understanding tasks, the LLM is first tasked with finding nodes connected to a given node to examine its retrieval capability. To assess multi-hop state tracking, the model must then determine the shortest path between two given nodes. Finally, to demonstrate global context understanding, the LLM is queried to find the longest path within the graph, a task requiring a holistic comprehension of the entire graph structure. Importantly, by presenting tasks of varying complexity under the *same context* that describes the graph or translation rules, we ensure that differences in model performance across tasks are solely attributed to the task difficulty. This design choice allows us to accurately assess the models' capabilities associated with different tasks without introducing confounding factors that arise when each task has a different context.

On SYNC, we evaluate 12 open-source and 2 proprietary LLMs that support a context length of 128K or longer, which reveals a consistent degradation in performance as the complexity of tasks increases. Notably, on the most challenging tasks requiring global context understanding, no model surpasses 25% accuracy. Compared with existing synthetic benchmarks, SYNC proves to be more effective in differentiating model capabilities, offering clearer alignment between task difficulty and performance. We further conduct experiments without the usage of chain-of-thought (CoT), where models struggle to maintain reasonable performance, which indicates the necessity of CoT on SYNC and again demonstrates the difficulty of our tasks. Additionally, we examine the correlation between our tasks and realistic tasks, revealing that identifying the shortest path in a graph can be a good predictor of real-world performance.

Our contributions can be summarized as follows:

1. We propose a new long-context evaluation benchmark, SYNC, which comprises synthetic contexts including graphs and unseen languages. Tasks requiring different levels of capabilities are designed based on the same contexts, enabling accurate assessment of model capabilities.

2. We benchmark 14 LLMs (12 open-source and 2 proprietary) on SYNC, revealing that existing LLMs face a challenge when handling tasks beyond retrieval on long contexts.

3. We conduct thorough analyses of our benchmark, including comparisons with existing synthetic benchmarks, an investigation into the effect of chain-of-thought reasoning, and a study of correlation between our tasks and realistic tasks. These analyses validate the difficulty of SYNC, illustrate the benefit of shared contexts, and indicate that our tasks can predict real-world performance.

2 Related Work

Early long-context evaluation benchmarks (Shaham et al., 2023; Tay et al., 2021) are gradually falling behind the advancements of LLMs with long context windows (Ainslie et al., 2023; Liu et al., 2023a; Chen et al., 2023; Peng et al., 2023; Team et al., 2024), due to the insufficient coverage of model context lengths (128K and longer) by the included data (Kočiský et al., 2018; Zhong et al., 2021; Huang et al., 2021; Wang et al., 2022). Recent benchmarks aim to address this gap by developing tasks featuring significantly longer contexts.

Realistic Tasks. Realistic tasks assess the practical performance of LLMs in applications closely aligned with real-world scenarios. Unlike synthetic tasks, these provide a more representative evaluation of long-context capabilities. However, realistic tasks are challenging to construct, and controlling the length and complexity of data points can be difficult.

Several benchmarks have emerged to comprehensively evaluate LLMs across diverse realistic applications. For instance, NovelQA (Wang et al., 2025), LongBench (Bai et al., 2024a), Nocha (Karpinska et al., 2024), ∞Bench (Zhang et al., 2024b), BABILong (Kuratov et al., 2024), BAMBOO (Dong et al., 2024), Loong (Wang et al., 2024), and LongCite (Zhang et al., 2024a) emphasize question-answering tasks involving lengthy narratives or multiple documents. For long-document summarization, benchmarks such as L-Eval (An et al., 2024) and LooGLE (Li et al., 2024a) provide a variety of relevant tasks. Furthermore, benchmarks like LongBench v2 (Bai et al., 2024b) and Long Code Arena (Bogomolov et al., 2024) assess repo-level code understanding, while LOFT (Lee et al., 2024) evaluates retrieval-augmented generation (RAG) tasks in extensive contexts. Finally, LongICLBench (Li et al., 2024b) and ManyICLBench (Zou et al., 2025) specifically target the evaluation of long-context models in many-shot in-context learning scenarios.

Synthetic Tasks. Synthetic tasks are specifically designed to rigorously test LLMs through artificially constructed contexts. Their primary advantage is the ease of generating data points, enabling precise control over context length and difficulty.

One of the most widely used synthetic tasks is Needle-in-a-Haystack (NIAH) (Kamradt, 2023), where models must retrieve a fact statement embedded within a large volume of random text. Synthetic tasks have also been incorporated into benchmarks that simutaineously contain realistic tasks, such as LongBench v2 (Bai et al., 2024a) and HELMET (Yen et al., 2024), yet they are mostly retrieval tasks similar to NIAH. Beyond extending NIAH, RULER (Hsieh et al., 2024) introduces tasks demanding more complex capabilities, such as state tracking.

Despite these efforts, current synthetic tasks remain limited in scope, primarily assessing retrieval capabilities. A broader limitation in multi-task benchmarks is the use of varying input contexts across tasks, which introduces confounding factors that hinder fair comparisons of model proficiency across different capabilities.

3 SYNC Task Creation

In this section, we introduce our benchmark, SYNC, a suite of synthetic tasks designed to evaluate varying capabilities of LLMs when processing long contexts. SYNC spans two domains: graph understanding (§3.1) and unseen language translation (§3.2). The domains are selected based on three criteria: (1) the domains can accommodate tasks that challenge different levels of model capabilities and can be adapted in difficulty for future models, (2) automatic sample construction is feasible, and (3) automatic evaluation is reliable. The contexts for these tasks are formed by descriptions of graphs and translation rules, respectively, and are supplemented with task-irrelevant information to increase the context length. For each domain, we consider three tasks of increasing complexity, evaluating the model's capabilities in information *retrieval*, state *tracking*, and *global* context understanding. We discuss key properties that distinguish our tasks from existing synthetic benchmarks in §3.3, including (1) targeting capabilities of varying levels; and (2) sharing contexts for controlled comparison.

Context
`You will answer a given question based on a directed acyclic graph. The edges of the graph are hidden within the following text. Make sure to memorize them. The nodes in the graph are: Node 1, Node 2, Node 3, Node 4, Node 5. [haystack] There is a directed edge from Node 1 to Node 2. [haystack] There is a directed edge from Node 2 to Node 3. [haystack] There is a directed edge from Node 2 to Node 4. ...`
Task Query
[Retrieval] Connected Node: `What are the nodes with directed edges from Node 1?`
[Tracking] Shortest Path: `What is the shortest path from Node 1 to Node 3?`
[Global] Longest Path: `What is the longest path in the graph?`

Table 1: Example of graph understanding tasks. The context interleaves essential graph details with haystack to extend the context length.

3.1 Tasks on Graph Understanding

We generate random directed acyclic graphs (DAGs) based on the number of nodes and the edge density (i.e., the probability that an edge exists between two nodes). To adjust the difficulty, we change the number of nodes in each graph. Each graph is presented to the model by listing its nodes and edges, as shown in Table 1. To extend the context length without overly increasing task complexity, we follow the needle-in-the-haystack approach and interleave the graph description with redundant but topically consistent information. Specifically, we repeatedly state that there is no self-cycle at each node (e.g., "There is no directed edge from Node 1 to Node 1"). Since the models are informed that the graphs are acyclic, the haystack does not provide extra clues for solving the tasks.

The **Connected Node** task requires the model to identify all nodes that have outgoing directed edges from a queried node. For each graph, a node is randomly selected as the query. This task tests the model's ability to retrieve relevant information with the query node as the key. For evaluation, we check if the set of nodes in the model response exactly match the reference set.

In the **Shortest Path** task, the model must find the shortest path from a given node to another. Intuitively, to effectively solve the problem, the model should maintain the state of its exploration in the graph, which keeps track of the explored and unex-

Context
Answer the question based on the given languages. These languages are created for special purposes and do not exist in the real world. Their vocabularies and bilingual dictionaries are as follows. Note that the vocabularies might be duplicated. The vocabulary of LL0: eszyci, dppu, ... [haystack] Dictionary from LL0 to LL1: dpamn -> aqdek; czrzib -> rqntu; ybzol -> ucc; ... [haystack] The vocabulary of LL1: ubmcrdu, erwkyr, ... [haystack] Dictionary from LL1 to LL2: ...
Task Query
[Retrieval] Single-hop Translation: What is the translation of "lrg eafi axry ikxxqq viw" from LL1 to LL2?
[Tracking] Multi-hop Translation: What is the translation of "ayg nrhu lsloiv mzg phx" from LL0 to LL2?
[Global] Letter Coverage: Find the three words in LL0 such that the union of the first letters of all their translations contains the maximum number of distinct letters.

Table 2: Example of translation-based tasks. Vocabularies are repeated to construct the haystack.

plored nodes during reasoning. If multiple shortest path exist, the model is allowed to return any valid shortest path. The model generated path is examined for the existence of each edge and the optimality of the path length. Note that the queried node pairs are chosen such that either no shortest path exists or the shortest path length is greater than 1, as a path length of 1 reduces the task to simple retrieval.

Finally, we test the model's global understanding of the graph by asking the model to extract the **Longest Path** from the whole graph. Similar to Shortest Path, the model must generate a path with fully valid edges and its length must match the length of the reference longest path.

3.2 Tasks on Unseen Language Translation

We also explore a domain closer to natural language by simulating translation between synthetic languages. For each language, we generate a vocabulary by randomly determining word lengths and selecting letters from the English alphabet. The translation rules are provided as a sequence of bilingual dictionaries. For instance, given three constructed languages L0, L1, and L2, two bilingual dictionaries are created to map L0 to L1 and L1 to L2. Each dictionary entry is limited to word-to-word translation, because phrase-level translation proves to be too difficult for existing models in our pilot experiment. The difficulty of the task can be controlled by varying the number of languages constructed. Each bilingual dictionary, containing task-relevant information, appears only once in the context, while the vocabularies of created languages are taken as haystack.

In **Single-hop Translation**, the model is provided with a source text (more than one word) in one synthetic language and must translate it into another language. Importantly, there exists a direct bilingual dictionary between the selected source and target languages, so that the model can solve the task by retrieving corresponding translations using words in the source text as keys.

A more challenging task, **Multi-hop Translation**, further requires the model to perform a sequence of translations across multiple languages. Without a direct bilingual dictionary between the source and target languages, the model must correctly apply consecutive bilingual dictionaries while keeping track of the translated outputs across the intermediate languages. Both single-hop and multi-hop translation are evaluated with exact match of the reference target text.

Letter Coverage. In this task, the model needs to identify three words in the source language, such that the union of the first letters of all their translations across every language contains the maximum number of distinct letters. This task evaluates the model's ability to fully understand and leverage all provided translation rules. During evaluation, we obtain all translated words for the model-selected words and compare the size of the union of first letters with the reference value (exact match of the size).

3.3 Properties of SYNC

We highlight several important properties of SYNC that differentiates it from existing synthetic benchmarks for long-context evaluation.

Varying Levels of Capabilities. Each domain contains tasks that differs in the *number of hops* and the *hop range*, which estimate the levels of capabilities required for task solving. A hop refers to one piece of information within the context that is needed to solve the task. When multiple hops *must* be chained to correctly solve the task, the distance between consecutive hops is the hop range. A higher hop count requires the model to identify more pieces of information, while a large hop range tests the model's ability to combine information scattered across a wide range of the context.

Model	Connected Nodes 32K	64K	128K	Shortest Path 32K	64K	128K	Longest Path 32K	64K	128K
Llama-3.3-70B-Instruct	98.7	92.7	11.3	57.3	46.0	8.0	18.7	16.0	0.0
Mistral-Large-Instruct	90.0	52.7	12.7	57.3	42.0	8.7	22.0	4.0	0.0
DeepSeek-Distill-Llama-70B	90.7	74.0	2.7	52.7	52.7	0.0	13.3	11.3	0.0
DeepSeek-Distill-Qwen-32B	74.7	56.0	20.0	55.3	37.3	8.7	13.3	10.0	0.0
GPT-4o	94.7	93.3	**96.0**	77.3	**77.3**	70.7	9.3	8.0	2.7
Gemini-2.0-Flash	**100.0**	**98.7**	88.0	**80.0**	76.0	**71.3**	**37.3**	**26.0**	**26.7**

Model	Single-hop Translation 32K	64K	128K	Multi-hop Translation 32K	64K	128K	Letter Cover 32K	64K	128K
Llama-3.3-70B-Instruct	84.0	86.0	0.0	37.3	33.3	0.0	**1.3**	1.3	0.0
Mistral-Large-Instruct	68.7	40.7	3.3	18.7	12.7	0.0	**1.3**	0.0	0.0
DeepSeek-Distill-Llama-70B	82.7	72.0	0.0	38.7	26.7	0.0	**1.3**	0.7	0.0
DeepSeek-Distill-Qwen-32B	74.0	38.7	8.7	45.3	20.0	0.0	**1.3**	1.3	0.0
GPT-4o	80.7	78.0	69.3	70.0	71.3	**51.3**	**1.3**	0.7	0.0
Gemini-2.0-Flash	**98.7**	**90.7**	**80.0**	**93.3**	**80.7**	27.3	0.7	**2.0**	0.0

Table 3: Performance of models with more than 30B parameters on SYNC. Performance of other models is reported in Appendix B. The best model in each setup is **bolded**. Performance is visually represented by a color scale from white (0) to green (100). From left to right, the tasks demand retrieval, state tracking, and global context understanding capabilities. Existing LLMs struggle with tasks beyond simple retrieval, suffering significant degradation on state tracking and global context understanding tasks.

Although NIAH tasks can involve retrieving multiple values in the context (Kamradt, 2023), their *hop range* is effectively zero because each necessary key-value pair can be retrieved independently. In contrast, our suite spans simple retrieval tasks to more complex ones (Shortest Path and Multi-hop Translation) that demand both a higher number of hops and longer hop ranges. Furthermore, we include tasks that require understanding all relevant information in the context (Longest Path and Budget-Aware Translation), maximizing both hops and ranges. Based on the qualitative analysis of hop counts and ranges, we categorize our tasks into *retrieval*, *tracking*, and *global understanding* tasks.

Shared Context across Tasks. Within each domain, we reuse the *same context* for three tasks of varying difficulty. Sharing the same context decouples the difficulty stemming from the context itself from the complexity of the task, allowing for a *controlled comparison of model capabilities* at different levels. Existing synthetic benchmarks such as RULER use different contexts for tasks of varying complexity (Hsieh et al., 2024), which obscures the assessment of the gap between capabilities.

4 Experiments

Models. We benchmark 14 LLMs, including 12 open-source models and 2 proprietary models, all of which can consume 128K or more tokens. Details of the models are provided in Appendix A. All models are evaluated under the 0-shot setting, as our pilot experiments showed that human-aligned models perform worse with in-context learning demonstrations. Due to high computational cost, for each setup, we ran model inference with greedy decoding once.

Benchmark Configurations. For graph understanding tasks, we generate DAGs with varying sizes. Specifically, we consider graphs with 10, 15, and 20 nodes. For each node count configuration, 50 DAGs are generated with an edge density of 0.15, resulting in a total of 150 graphs. To guarantee that each graph is topologically unique, we compute the hash of its canonical form. Node labels are assigned sequentially, starting from 0.

For translation tasks, we construct vocabularies and bilingual dictionaries with different numbers of languages. We consider three configurations with 3, 5, and 7 languages, respectively. For each configuration, 50 distinct sets of vocabularies and dictionaries are generated. Each language comprises 250 words, with each word having a length between 3 and 7 letters. Phrases are limited to at most 5 words, and each bilingual dictionary contains 50 entries.

We insert haystack to create tasks with context lengths of 32K (32,768), 64K (65,536), and 128K (131,072) tokens, as counted by the tokenizer of Mistral-Large-Instruct.

These parameters are freely adjustable to alter data complexity and diversity. We do not expand the graph size or increase the number of languages further, because the complexity might surpass the model's capability for a meaningful evaluation.

5 Results

5.1 Main Results

Table 3 shows the performance of the six models with more than 30B parameters on SYNC. Results for other models are provided in Appendix B. Although current LLMs can consume long contexts, they still **struggle with tasks beyond simple retrieval**. Among the six LLMs, four achieve over 70% accuracy on listing connected nodes and performing single-hop translations with context lengths up to 64K. However, only the two proprietary models, Gemini-2.0-flash and GPT-4o, maintain over 70% accuracy on the tracking tasks (i.e., Shortest Path and Multi-hop Translation). On the most challenging global understanding tasks (i.e., Longest Path and Letter Coverage), all models achieve below 40% accuracy.

Open-source models experience **catastrophic degradation at 128K context length**. Even Llama-3.3-70B, which remains stable from 32K to 64K, suffers a sudden drop at 128K. Upon manual inspection, we find that at such extreme lengths, models often fail to follow prompt instructions, resulting in invalid responses. We hypothesize that instruction-following abilities diminish when models approach their maximum context length, likely because they have less exposure to very long inputs during training.

Comparisons with Other Synthetic Tasks. For comparisons, we include the extraction of corresponding keys with given values from JSON file (JSON KV) (Liu et al., 2023b; Yen et al., 2024). We also consider two tasks from RULER (Hsieh et al., 2024): NIAH tests augmented with multiple values, which are reported to be more challenging than other synthetic NIAH tests; and variable tracking, which targets the state-tracking capability.

Table 4 presents the performance of GPT-4o and Gemini-2.0-flash on SYNC and existing synthetic tasks. The tasks in SYNC are **more difficult overall**, especially for those requiring capabilities beyond retrieval. While existing benchmarks extend standard NIAH with additional key-value pairs and more distracting content, fundamentally they only test retrieval. In SYNC, state tracking and global context understanding tasks require gathering distant clues and synthesizing them, demanding more advanced reasoning. Furthermore, it is noteworthy that high performance on our retrieval tasks relies on the usage of CoT during inference (discussed in §5.2), whereas existing synthetic tasks generally do not. This demonstrates that SYNC offers *sufficient complexity* to challenge future, more advanced models.

Task	GPT-4o 64K	GPT-4o 128K	Gemini-2.0-flash 64K	Gemini-2.0-flash 128K
JSON KV	100.0	100.0	98.0	92.0
RULER				
NIAH Multi-Value	100.0	99.5	99.8	87.8
Variable Tracking	99.6	<u>99.8</u>	<u>100.0</u>	<u>100.0</u>
SYNC *Graph*				
Connected Nodes	94.0	96.0	92.0	88.0
Shortest Path	76.7	70.7	76.0	71.3
SYNC *Translation*				
Single-hop Trans.	78.0	69.3	90.7	80.0
Multi-hop Trans.	71.3	51.3	80.7	27.3

Table 4: Performance of GPT-4o and Gemini-2.0-flash on SYNC and other synthetic tasks. We highlight perfect performance with green. Within the same benchmark, state-tracking tasks that yield higher performance than retrieval tasks are <u>underlined</u>. Using the same context across tasks mitigates the counfounding effect of input context on task difficulty, ensuring tasks requiring more complex capabilities are more challenging.

Sharing the same input context across tasks enables **controlled comparisons of model capabilities**. RULER uses different input contexts for each task, making task performance attributable to both the difficulty of understanding the context and the complexity of the capabilities required to solve the task. Although state tracking is intuitively more complex than retrieval, the absolute performance on RULER's variable tracking task is often higher than that on the multi-value NIAH task. On SYNC, model performance declines as task complexity increases.

Controlled comparisons also allow for precise analysis of model capabilities. For example, Gemini-2.0-flash suffers a more significant decline in multi-hop translation than in single-hop translation when the same input context increases from 64K to 128K tokens. This reveals that while the model retains its ability to understand lengthened contexts and perform retrieval, it lacks the robust state-tracking capability needed to support multi-hop reasoning in longer contexts.

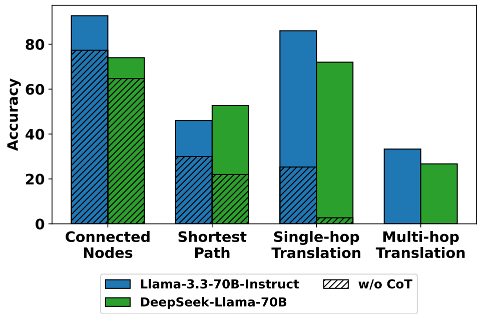

Figure 1: Model performance with and without CoT. Without CoT, performance decreases substantially on SYNC.

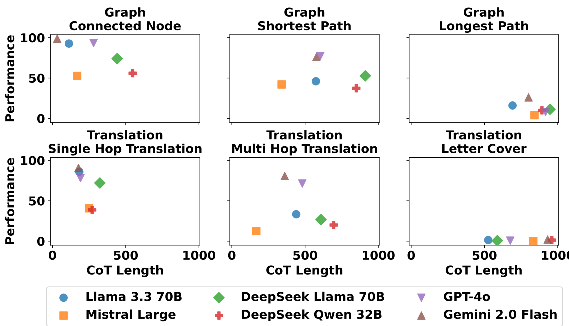

Figure 2: Accuracy and average CoT length for each task in SYNC at 64K context length. Complex tasks prompt longer CoTs, yet more CoT tokens do not necessarily lead to better performance.

5.2 Analysis of Chain-of-Thought (CoT)

In our main experiments, we allow models to use CoT in their responses. To study the effects of CoT, we force the model to output the answer directly by prepending the answer prefix of each task to the model response. As shown in Figure 1, both Llama-3.3-70B and its DeepSeek R1 distilled variant have significant performance drops without CoT. Notably, both models approach 0% accuracy on multi-hop translations when CoT is disabled, indicating the **necessity of CoT** on SYNC.

Figure 2 shows the CoT length and accuracy across different tasks at a 64K context length. The average CoT length evidences the proposed task complexity ordering, as models generally produce **longer CoTs for more complex tasks**. For retrieval tasks, most models generate fewer than 500 CoT tokens. In contrast, global context understanding tasks often elicit CoTs exceeding 500 tokens, with DeepSeek-distilled models reaching 1,000 tokens, though they still fail to solve these tasks.

We further investigate the scaling effect of CoTs by forcing models to generate CoTs of different lengths ranging from 0 to 8192 tokens (Figure 3). Llama-3.1-8B and Llama-3.3-70B are not explicitly trained for long CoTs and therefore do not consistently benefit from longer reasoning chains across all tasks. Their DeepSeek-distilled variants show performance gains with longer CoTs on the Shortest Path and Longest Path tasks, but not on translation tasks. Per human inspection, both models make translation errors at the intermediate steps (usually the first step) and do not self correct. The discrepancy in domain performance highlights the importance of incorporating multiple domains in our benchmark. On graph understanding tasks, the performance of DeepSeek-distilled models plateaus with long CoTs, suggesting that SYNC has *sufficient capacity* for evaluating reasoning models.

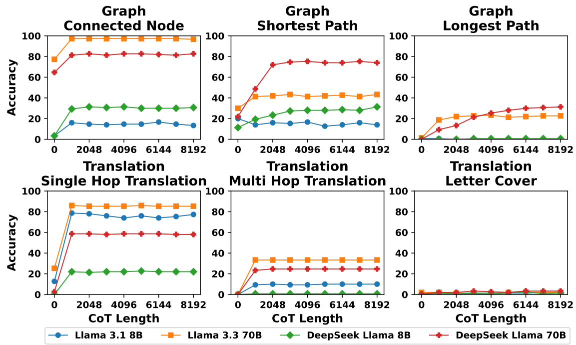

Figure 3: Accuracy under enforced CoT length for each task at 64K context length. DeepSeek-distilled models show improvements with longer CoT on graph understanding tasks, but not on translation tasks.

5.3 Correlation with Realistic Tasks

We study the correlation between SYNC and realistic tasks to understand how well our benchmark can predict real-world performance. We leverage the data released by Yen et al. (2024), which adapts existing datasets for long-context evaluation. Specifically, we include Natural Questions (Kwiatkowski et al., 2019) and HotpotQA (Yang et al., 2018) in the retrieval-augmented generation setup, single-document QA from InfiniteBench (Zhang et al., 2024b) and NarrativeQA (Kočiský et al., 2018), as well as single-document summarization using InfiniteBench. To explore in-context learning under long-context conditions, we use BANKING77 (Casanueva et al., 2020) and CLINC150 (Larson et al., 2019), where long contexts are formed by the demonstration examples. Additionally, we take the subsets from

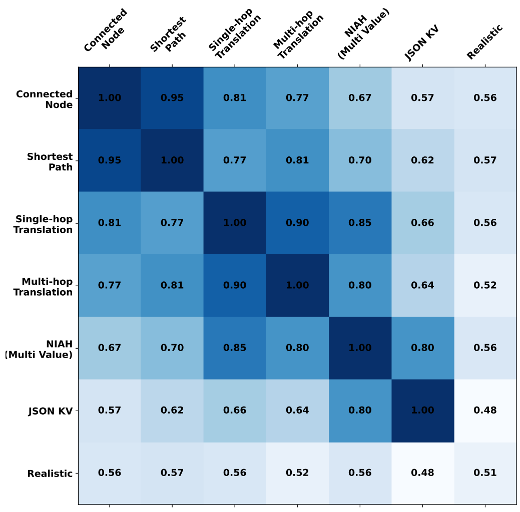

Figure 4: Spearman rank correlation between synthetic tasks and realistic tasks. Higher values indicate stronger alignment in the model rankings produced by two tasks. Correlations with realistic tasks are aggregated with macro average, with detailed breakdown in Appendix C.

LongBench v2 covering multi-document QA and code-based QA (Bai et al., 2024b). We follow the suggested evaluation metrics paired with the released data.

We compute the Spearman ranking correlation between each of the tasks in SYNC (excluding global context understanding tasks, which most models fail at) and the aforementioned realistic tasks. We measure the correlations based on all 14 models at 32K and 64K context lengths, then take the average across context lengths. We do not include 128K because most models perform near zero at that length, making ranking correlations uninformative. To compare with overall realistic tasks, we also aggregate correlations across realistic tasks. Note that the aggregated realistic task does not perfectly correlate with itself, as macro average is employed.

As shown in Figure 4, among all synthetic tasks, the Shortest Path task in SYNC achieves the highest overall correlation with realistic tasks. We think that the real-world tasks we study might be relying more on the state tracking capability. Although other tasks in SYNC do not surpass the NIAH task augmented with multi values, they still show higher correlation with realistic tasks than the other baseline synthetic task. Interestingly, SYNC tasks can even exceed the aggregated correlation that realistic tasks have with each other, suggesting that our tasks can serve as **proxies for real-world performance**.

	Shortest Path			Longest Path		
Model	**NA**	**IV**	**SO**	**NA**	**IV**	**SO**
Llama-3.3-70B-Instruct	8.0	44.7	1.3	5.3	45.3	33.3
Mistral-Large-Instruct	8.7	49.3	**0.0**	24.0	35.3	36.7
DeepSeek-Llama-70B	**4.7**	42.0	0.7	**0.0**	59.3	**29.3**
GPT-4o	11.3	**11.3**	**0.0**	18.0	22.0	52.0
Gemini-2.0-Flash	8.0	16.0	**0.0**	12.0	**15.3**	46.7

Table 5: Percentage of different error types on Shortest Path and Longest Path tasks at 64K context length. NA: No Answer; IV: Invalid Path; SO: Suboptimal Path. Invalid Path is the most common error on Shortest Path, while models start to produce more suboptimal paths on Longest Path.

5.4 Error Analysis

To better understand model behavior, we perform an error analysis on the Shortest Path and Longest Path tasks. Table 5 presents the distribution of error types at a 64K context length, categorized as follows: (1) *No Answer*—the model fails to produce a response (example: the model repeats the context *"The longest path in the graph is from Node 9 to Node 0. There is no directed edge from Node 9 to Node 9 ..."*); (2) *Invalid Path*—the predicted path includes at least one edge not present in the graph (example: the model generates *"Longest Path: Node 0, Node 9, Node 10, Node 12, Node 3, Node 8, Node 18, Node 11, Node 19"* while the edge from Node 10 to Node 12 does not exist in the graph); (3) *Suboptimal Path*—the predicted path is valid but its length differs from the reference shortest or longest path (example: the model generates *"Longest Path: Node 19, Node 15, Node 10, Node 8, Node 7, Node 5, Node 9"* while the path length is shorter than 9, the length of the longest path).

A notable portion of errors falls under *No Answer*, likely due to degraded instruction-following ability as context length increases. In the Shortest Path task, suboptimal paths are rare, whereas they are more common in the Longest Path task, where the absence of a fixed start or end node expands the solution space. This pattern suggests that models often resort to brute-force search rather than employing more efficient strategies (e.g., linear-time algorithms for DAGs).

Invalid Path is prevalent in both tasks. While models can often identify valid local connections, maintaining correctness over longer chains of reasoning remains difficult. Manual inspection of 20 invalid-path cases revealed that all errors occurred in the middle of the path, suggesting that while shallow reasoning is manageable, deeper multi-hop reasoning still poses a significant challenge.

6 Conclusions

We introduce SYNC, a long-context evaluation benchmark consisting of synthetic contexts based on graphs and translation rules. Our benchmark includes three tasks per constructed context, each of which targets a specific model capability among retrieval, state tracking, and global context understanding. By eliminating variation in the input context, SYNC achieves more controlled evaluation of model capabilities. Experiments with 14 LLMs show that SYNC is more challenging in two ways: (1) it includes tasks requiring more complex capabilities; (2) chain-of-thought (CoT) reasoning is needed to solve the tasks in SYNC. We also quantitatively illustrate the importance of sharing input contexts, via comparisons with a popular synthetic benchmark. Further analyses reveal the potentials of SYNC for predicting performance of realistic tasks.

7 Limitations

SYNC includes tasks targeting three capabilities per domain: retrieval, tracking, and global understanding. However, model capabilities can be more diverse and complex. For example, some capabilities might entangle each other, making it hard to separate them. We assume that retrieval, tracking, and global understanding are the most significant model capability, and we only consider them when building the benchmark. The tasks in SYNC evaluate specific skills of LLMs, such as math and algorithmic reasoning. While these skills are critical for their performance in many real-world situations, we recognize that the skills we cover are limited. We also note that our dataset does not aim to replace realistic datasets. Rather, our objective is to improve existing synthetic datasets and complement existing LLM evaluation.

Our benchmark is configured into a 0-shot setup, as we observe degraded performance with few-shot demonstrations. 0-shot prompting also allows the usage of longer input contexts. Nevertheless, we recognize that the 0-shot setup relies on models' instruction-following capabilities, and therefore might not be applicable for certain models (e.g., base LLMs).

8 Ethical Considerations

In §5.3, tasks in SYNC show higher correlations with realistic tasks than most baseline synthetic tasks and even some of the realistic tasks. However, we note that correlations varies a lot across tasks, as shown in the detailed breakdown (Figure 5 and 6). Therefore, performance on SYNC should never be the single criteria for determining the usage of models in real-world applications. In addition to experiments on SYNC, models to be deployed should also be experimented on proper real-world tasks to mitigate the potential risks.

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A Experiment Details

Models. We benchmark 7 open-source LLMs that are pre-trained from scratch, including Llama-3.2-3B, Llama-3.1-8B, Llama-3.3-70B (Grattafiori et al., 2024), Mistral-Nemo-2407, Mistral-Large-2411 (AI, 2024), Phi-3.5-mini (Abdin et al., 2024), and GLM-4-9B (GLM et al., 2024). We use

Model	# of Para.	Context Len
Open-source Models		
Llama-3.2-3B-Instruct	3B	131072
Llama-3.1-8B-Instruct	8B	131072
Llama-3.3-70B-Instruct	70B	131072
Mistral-Nemo-Instruct-2407	12B	131072
Mistral-Large-Instruct-2411	123B	131072
Phi-3.5-mini-Instruct	4B	131072
GLM-4-9B-Chat	9B	131072
DeepSeek Distilled Models		
DeepSeek-R1-Distill-Llama-8B	8B	131072
DeepSeek-R1-Distill-Llama-70B	70B	131072
DeepSeek-R1-Distill-Qwen-7B	7B	130172
DeepSeek-R1-Distill-Qwen-14B	14B	130172
DeepSeek-R1-Distill-Qwen-32B	32B	130172
Proprietary Models		
GPT-4o-2024-11-20	-	128000
Gemini-2.0-flash-001	-	1000000

Table 6: Information about the models used in our experiments. All models support 128K tokens.

their human-aligned variants which can better follow instructions. Besides models that are pre-trained from scratch, 5 models that are further fine-tuned with data distilled from DeepSeek-R1 are tested: DeepSeek-R1-Distill-Llama-8B, DeepSeek-R1-Distill-Llama-70B, DeepSeek-R1-Distill-Qwen-7B, DeepSeek-R1-Distill-Qwen-14B, and DeepSeek-R1-Distill-Qwen-32B (DeepSeek-AI et al., 2025). We also include 2 proprietary models, GPT-4o (OpenAI et al., 2024a) and Gemini-2.0-flash (Team et al., 2024). Table 6 summarizes these models.

Infrastructure. The inference is performed with vLLM (Kwon et al., 2023) on 8 A40 GPUs.

Usage of AI Assistant. We use ChatGPT (OpenAI et al., 2024a) for correcting grammar errors in our writing.

B Additional Results

We provide the full results of all models on the synthetic tasks in SYNC in Table 7.

C Correlation Breakdown

We report the detailed breakdown of ranking correlation between synthetic tasks and realistic tasks at 32K and 64K context length in Figures 5 and 6.

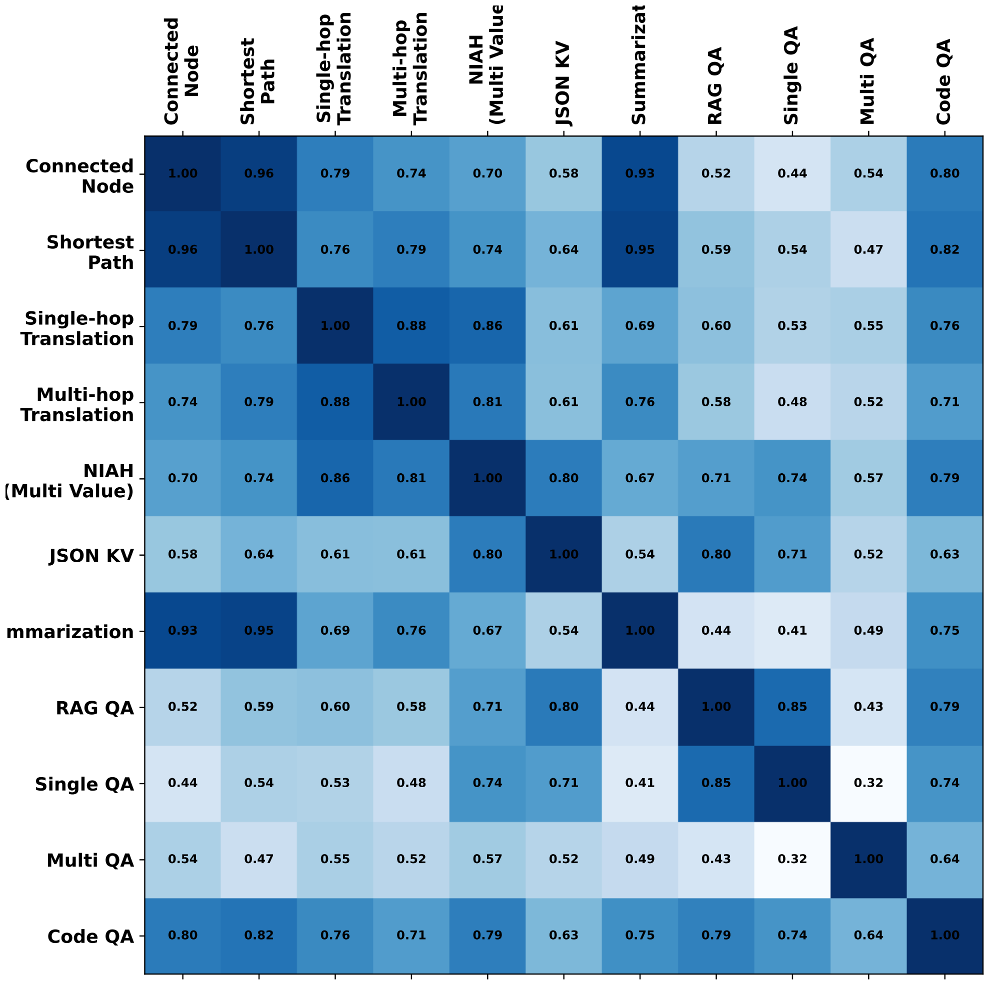
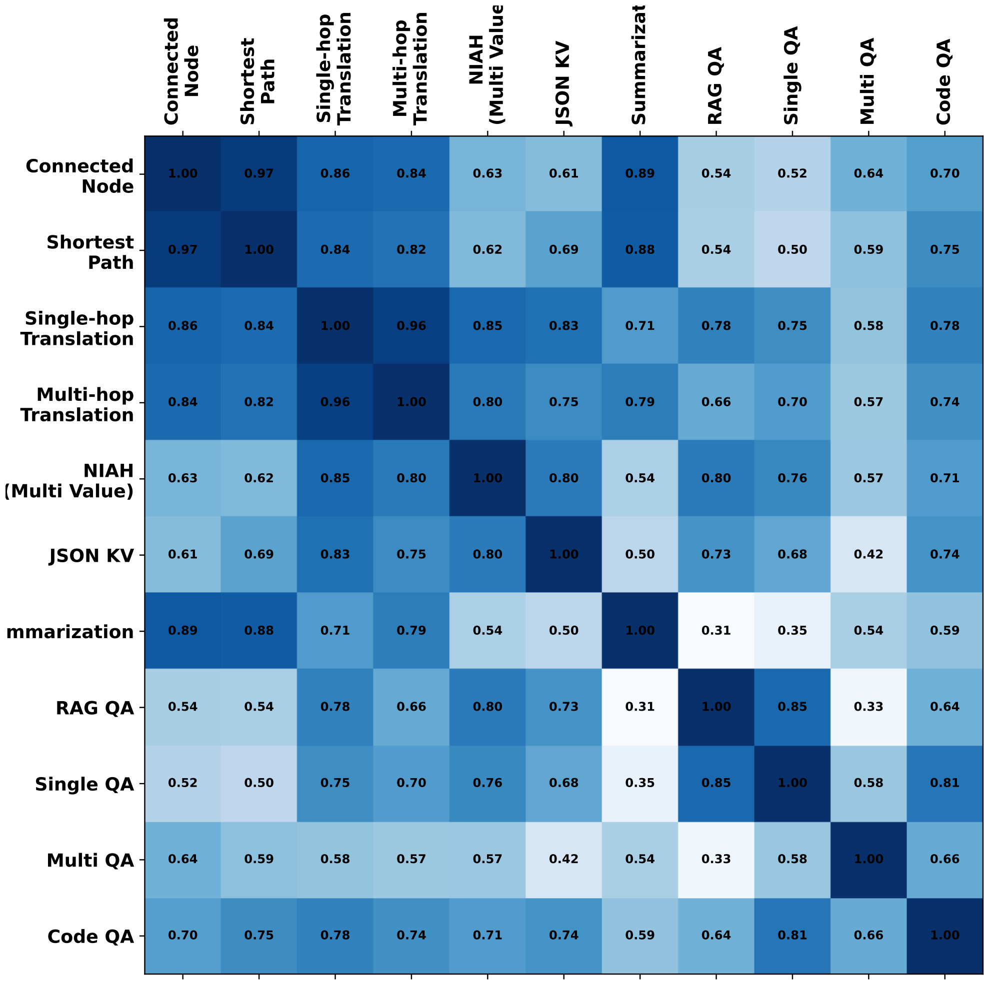


Figure 5: Spearman rank correlation between synthetic tasks and realistic tasks at 32K.



	Connected Node	Shortest Path	Single-hop Translation	Multi-hop Translation	NIAH (Multi Value)	JSON KV	Summarization	RAG QA	Single QA	Multi QA	Code QA
Connected Node	1.00	0.97	0.86	0.84	0.63	0.61	0.89	0.54	0.52	0.64	0.70
Shortest Path	0.97	1.00	0.84	0.82	0.62	0.69	0.88	0.54	0.50	0.59	0.75
Single-hop Translation	0.86	0.84	1.00	0.96	0.85	0.83	0.71	0.78	0.75	0.58	0.78
Multi-hop Translation	0.84	0.82	0.96	1.00	0.80	0.75	0.79	0.66	0.70	0.57	0.74
NIAH (Multi Value)	0.63	0.62	0.85	0.80	1.00	0.80	0.54	0.80	0.76	0.57	0.71
JSON KV	0.61	0.69	0.83	0.75	0.80	1.00	0.50	0.73	0.68	0.42	0.74
mmarization	0.89	0.88	0.71	0.79	0.54	0.50	1.00	0.31	0.35	0.54	0.59
RAG QA	0.54	0.54	0.78	0.66	0.80	0.73	0.31	1.00	0.85	0.33	0.64
Single QA	0.52	0.50	0.75	0.70	0.76	0.68	0.35	0.85	1.00	0.58	0.81
Multi QA	0.64	0.59	0.58	0.57	0.57	0.42	0.54	0.33	0.58	1.00	0.66
Code QA	0.70	0.75	0.78	0.74	0.71	0.74	0.59	0.64	0.81	0.66	1.00

Figure 6: Spearman rank correlation between synthetic tasks and realistic tasks at 64K.

Model	Connected Nodes 32K	64K	128K	Shortest Path 32K	64K	128K	Longest Path 32K	64K	128K
Llama 3.2 3B	14.0	12.0	2.7	12.7	14.0	6.7	0.0	0.0	0.0
Llama 3.1 8B	14.7	12.0	2.7	15.3	20.0	3.3	0.7	0.0	0.0
Llama 3.3 70B	98.7	92.7	11.3	57.3	46.0	8.0	18.7	16.0	0.0
Mistral Nemo	10.7	1.3	8.7	5.3	4.0	1.3	0.0	0.0	0.0
Mistral Large	90.0	52.7	12.7	57.3	42.0	8.7	22.0	4.0	0.0
DeepSeek Llama 8B	45.3	22.0	13.3	16.7	28.7	0.0	1.3	0.7	0.0
DeepSeek Llama 70B	90.7	74.0	2.7	52.7	52.7	0.0	13.3	11.3	0.0
DeepSeek Qwen 7B	8.7	4.7	7.3	2.7	0.0	0.0	0.0	0.0	0.0
DeepSeek Qwen 14B	44.7	21.3	12.7	36.0	20.0	11.3	4.0	2.7	0.0
DeepSeek Qwen 32B	74.7	56.0	20.0	55.3	37.3	8.7	13.3	10.0	0.0
Phi 3.5 mini	12.7	7.3	8.7	12.7	15.3	13.3	0.7	0.0	0.0
GLM 4 9B	29.3	40.7	27.3	20.0	26.0	19.3	0.0	0.0	1.3
GPT-4o	94.7	93.3	**96.0**	77.3	**77.3**	70.7	9.3	8.0	2.7
Gemini 2.0 Flash	**100.0**	**98.7**	88.0	**80.0**	76.0	**71.3**	**37.3**	**26.0**	**26.7**

Model	Single-hop Translation 32K	64K	128K	Multi-hop Translation 32K	64K	128K	Letter Cover 32K	64K	128K
Llama 3.2 3B	35.3	8.0	1.3	0.0	0.0	0.0	0.0	0.7	0.0
Llama 3.1 8B	76.0	74.7	76.0	39.3	28.0	1.3	0.0	0.0	0.0
Llama 3.3 70B	84.0	86.0	0.0	37.3	33.3	0.0	**1.3**	1.3	0.0
Mistral Nemo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mistral Large	68.7	40.7	3.3	18.7	12.7	0.0	**1.3**	0.0	0.0
DeepSeek Llama 8B	38.7	24.0	0.0	5.3	0.7	0.0	0.7	0.7	0.0
DeepSeek Llama 70B	82.7	72.0	0.0	38.7	26.7	0.0	**1.3**	0.7	0.0
DeepSeek Qwen 7B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DeepSeek Qwen 14B	31.3	20.7	2.7	11.3	6.7	0.0	0.7	**2.0**	0.0
DeepSeek Qwen 32B	74.0	38.7	8.7	45.3	20.0	0.0	**1.3**	1.3	0.0
Phi 3.5 mini	6.0	0.7	0.7	0.0	0.0	0.0	0.0	0.7	0.7
GLM 4 9B	86.0	74.0	65.3	48.0	43.3	2.7	0.0	0.0	0.0
GPT-4o	80.7	78.0	69.3	70.0	71.3	**51.3**	**1.3**	0.7	0.0
Gemini 2.0 Flash	**98.7**	**90.7**	**80.0**	**93.3**	**80.7**	27.3	0.7	**2.0**	0.0

Table 7: Performance of all models on the synthetic tasks in SYNC. The best model for each task setup is **bolded**.