

Exploring In-Context Learning for Knowledge Grounded Dialog Generation

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Abstract

Large neural-based dialog generation models have been applied in many real-life scenarios, yet they are prone to hallucination and tend to produce factually inaccurate outputs which raise great concerns. To alleviate this problem, we propose a plug-and-play retrieval-based framework **IKA**, which leverages in-context learning and retrieval techniques to enhance LLMs on knowledge grounded dialog generation. We design thorough experiments on a large-scale knowledge graph with 1M+ facts (Moon et al., 2019) to investigate the effectiveness and generalization of our framework. Experiments show that our method surpasses previous training-based SOTA by a large margin, specifically **46.67%** in BLEU4, **26.01%** in ROUGE-L, **122.90%** in BARTScore and **30.50%** in Entity Coverage F1. Further analysis shows promising abilities of LLMs to perform knowledge-intensive tasks, which is previously considered weak and understudied.

1 Introduction

Existing knowledge grounded dialogue (KGD) systems aim to make use of external knowledge to produce reasonable dialogue responses (Ji et al., 2022; Dziri et al., 2021; Zhang et al., 2019; He et al., 2017). To introduce the KGD task, Figure 1 gives an example; the left side of the figure provides the corresponding knowledge graph, while the right side of the figure shows the dialogue history and the response. The goal of KGD is to generate fluent and faithful response based on context and knowledge.

The earlier works of KGD focus on the use of knowledge graphs, where sub-graphs are retrieved using entities and relationships given dialog history and relevant knowledge. Generally, they utilize a separate knowledge encoder module. Errors in knowledge retrieval stage may propagate to the generative model (Sarkar et al., 2022; Ji et al., 2022; Kang et al., 2022). This type of methods aims to

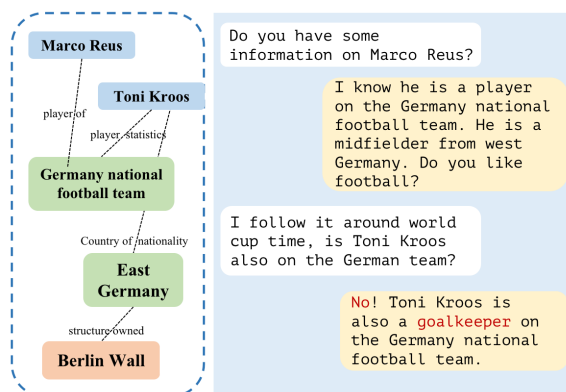


Figure 1: An example of conversation wherein the agent receives *correct* knowledge but still generates *hallucinated* response. Toni Kroos is the midfielder rather than the goalkeeper of Germany national football team, which contradicts the knowledge paths provided.

compensate for the lack of relevant knowledge in the generative model, which are usually inefficient in training and unsatisfactory in performance.

Recently, large language models (Brown et al., 2020; OpenAI, 2023) have been applied to a variety of tasks. They store rich parametric world knowledge through pre-training and are able to produce fluent and human-like responses. However, they uncontrollably generate content that is inconsistent with factual knowledge and even contain hallucinations (Shuster et al., 2021; Dziri et al., 2022b,a; Mielke et al., 2022). Thus, hallucination in large language models (Ji et al., 2023) is a big concern in real-world applications, as a growing number of users directly integrate LLMs into their daily pipelines without realizing this risk (Tiku, 2022). We also use GPT3.5(text-davinci-003) to conduct preliminary experiments on KGD, where the context and knowledge are concatenated as textual input to generate response, and find similar

hallucination problem. We can see the ability to leverage knowledge in LLMs is non-trivial. How to leverage knowledge is the focus of our research.

Large language models like GPT-3 (Brown et al., 2020) and LaMDA (Thoppilan et al., 2022) have demonstrated emergent in-context learning abilities, which becomes a new research paradigm for LLMs. In this paradigm, task definition, demonstration examples and target context are concatenated as the input prompt for LLMs. The example selection process is vital to the effectiveness of ICL (Min et al., 2022) We believe a more refined example **retrieval** stage based on both dialogue history and knowledge is needed. To the best of our knowledge, no previous work (Ji et al., 2022; Kang et al., 2022; Dziri et al., 2021) has explored the potential of ICL in knowledge grounded dialogue generation.

In order to overcome these issues, we propose **IKA** framework as an effective plug-and-play solution. The principle of IKA is to retrieve high quality in-context demonstrations to guide LLMs. A high-level overview is illustrated in Figure 2. IKA consists of three modules, a retrieval module for retrieving relevant examples based on history and knowledge, a DER module to improve the diversity of retrieved examples and a prompt constructing module to build the final input for LLMs. By plug-and-play it means no additional training or parameter updates are required. The retrieval module can be implemented by any retrieval methods, and the inference LLMs can be either open-source or black-box.

Experimental results show that our method significantly outperforms state-of-the-art (Ji et al., 2022) on OpendialKG(Moon et al., 2019). In automated evaluation, our framework is able to gain **46.67%** on BLEU4, **26.01%** on ROUGE-L, **122.90%** on BARTScore and **30.50%** on Entity Coverage F1. For the choice of retrieval method, our best results have **18.43%**, **27.75%** and **69.78%** relative gains on BLUE, ROUGE-L and BARTScore (Yuan et al., 2021) compared to random retrieval baseline. Our proposed diversify strategy achieves the highest faithfulness evaluation results. The quantitative and qualitative investigation further demonstrates its efficacy. In summary, our contributions are as follows:

- We are the first to apply in-context learning to knowledge grounded dialog generation. Ablation experiments demonstrate the outstanding performance of ICL for knowledge-intensive

task.

- We give a comprehensive empirical study on many aspects of ICL strategies in KGD, including the choice of retrieval methods, knowledge representation etc. These findings are valuable for a deeper understanding of LLMs.
- We propose a plug-and-play retrieval based framework called **IKA**(**I**n-context **K**nowledge grounded dialog **A**ugmenter). IKA is applicable across LLMs and significantly surpasses previous works (Ji et al., 2022; Sarkar et al., 2022; Dziri et al., 2021).

2 Related Works

2.1 Hallucination in Open-domain Dialogue Generation

How to reduce the false information in generated text is a popular research topic in natural language generation. Previous works have studied the hallucination in sub-field of NLG such as abstractive summarization or machine translation (Huang et al., 2021; Lee et al., 2018). Dialogue generation is different from above tasks in that it requires multi-turn, long-term interaction. Dziri et al. (2022b) propose to split hallucination in open-domain dialogue into intrinsic and extrinsic hallucination. Some methods propose to improve the transformer (Vaswani et al., 2017) architecture to increase dialog faithfulness. Xu et al. (2021) leverage light-weight adapter as knowledge expert to enhance GPT-2 (Radford et al., 2019). Wu et al. (2021) apply an inductive attention mechanism for self-attention-based generation models. Instead of improving the generation model itself, Dziri et al. (2021); Ji et al. (2022); Sarkar et al. (2022) propose to add extra module such as knowledge graph grounding module or re-ranking module to reduce hallucination.

2.2 In-context Learning

Large language models pre-trained on next-token prediction objective have been found to have the ability to adapt to new task with only a few examples as input (Brown et al., 2020), which means they can be applied to different tasks at inference time without expensive training. However, the theory and mechanism of in-context learning have not been well studied. Some researchers (Wang et al., 2023) argue that in-context learning happens when

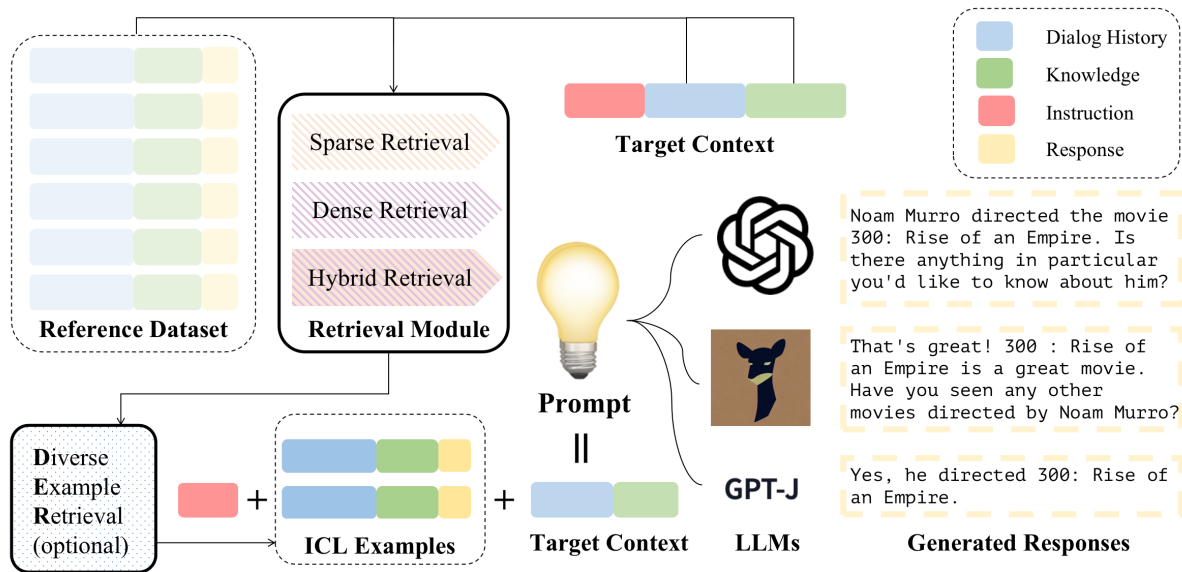


Figure 2: An overview of IKA framework.

a latent concept is inferred at test time. Olsson et al. (2022) contribute in-context learning ability of transformer-based model to the existence of "induction heads". Akyürek et al. (2022) further verify this hypothesis on toy linear regression. The example selection process has also become a popular research topic. Liu et al. (2021) propose to retrieve in-context examples using nearest neighbor algorithm. In supervised learning, the input-label correspondence is very important, but Min et al. (2022) argue that ground truth labels are not required in ICL, which is quite counter-intuitive.

3 Methodology

We propose a plug-and-play retrieval based framework called **IKA**(In-context **K**nowledge grounded dialog **A**ugmenter) to enhance LLMs' faithful generation ability. The overview of our method is presented in Figure 2. We conduct broad experiments on mainstream LLMs such as GPT-2 (Radford et al., 2019), GPT-J (Wang and Komatsuzaki, 2021), GPT-3 (Brown et al., 2020), GPT-4 (OpenAI, 2023) and Falcon (Almazrouei et al., 2023). Most of them are general purpose LLMs pre-trained on large-scale corpus and have not been fine-tuned or optimized for KGD task.

We find KGD especially suitable for in-context learning mainly for two reasons: (1). the provided knowledge is very helpful in selecting semantically similar demonstrations (2). how to leverage given knowledge and generate high quality

response is complex even for powerful LLMs. Recent work (Evanson et al., 2023) points out the similarity between training large language models and children's language acquisition, therefore we argue that similar mechanism may exist in prompting language models to perform specific task. An analogy is instructing a high school student to pass open-book exam. A smart teaching technique would be to provide some well selected input-output examples so that the student understands how to use given knowledge to produce high quality answers.

In this section, we first give a formal description of KGD task and introduce current research challenges. Then, we formulate KGD task under a conditional text generation framework using in-context learning techniques. In addition to traditional in-context examples selection strategies, we design several retrieval strategies to ground our selection process on dialogue history and relevant knowledge.

3.1 Task Definition

For dialogue systems, generating responses involves handling data samples that include a dialogue history H , a collection of utterances U that reflect interaction between human users and AI assistants.

Here we focus on knowledge grounded dialog task, which is an extended setting of dialogue response generation. In KGD task, the conversation system is typically equipped with a knowledge base that contains a wide range of information in the

form of text or triplets. Factual triplets are often presented in the form of (*subject*, *predicate*, *object*). The subject and object are entities in the knowledge graph, and predicate represents the relationship between the two. The goal of KGD is to generate faithful and informative response based on dialog history H and knowledge K . We have faithfully followed the setup of previous works (Zhou et al., 2021; Dziri et al., 2021; Ji et al., 2022).

3.2 Model KGD as Conditional Text Generation via In-Context Learning

We propose to model KGD as a conditional text generation (Hu and Li, 2021) problem. The output sequences are conditioned on the combination of instruction, in-context examples, dialog history and knowledge. To the best of our knowledge, we are the first to model KGD under the framework of in-context learning. Concretely, the probability of generating a target y given input x can be modeled as :

$$\mathcal{P}_{LM}(y|x) = \prod_{t=0}^n \mathcal{P}_{LM}(y_t|H, K, y_{<t}) \quad (1)$$

where LM denotes the parameters of language models, H denotes dialog history and K denotes knowledge. In the setting of in-context learning, examples are required to instruct LLMs, thus the above equation can be rewritten in the following form:

$$\mathcal{P}_{LM}(y_t|H, K, y_{<t}) = \sum_C \mathcal{P}_{LM}(y_t|H, K, C, y_{<t}) \mathcal{P}_r(C|H, K) \quad (2)$$

where C denotes the retrieved in-context examples given history and knowledge. Here we decompose the conditional text generation probability into the product of two terms. $\mathcal{P}_r(C|H, K)$ corresponds to the joint probability distribution of in-context examples where r denotes the example retrieval process. However, depending on different retrieval strategies, the joint probability distribution of examples can be modeled differently. For instance, we can randomly sample examples from reference dataset, the joint distribution of examples and the distribution of history and knowledge are independent, so $\mathcal{P}_r(C|H, K) = P_r(C)$. Previous work (Liu et al., 2021) shows that random sampling leads to unstable performance, and further argues to select examples that are semantically-similar to the target context, i.e. calculating $\mathcal{P}_r(C|H, K)$. In this work,

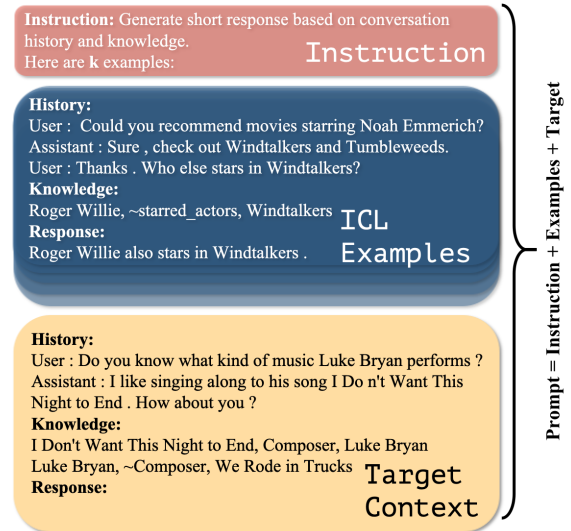


Figure 3: An example of prompt

we propose to model the dependency between examples, which can be expressed as:

$$\mathcal{P}_r(C|H, K) = \prod_{i=1}^n \mathcal{P}_r(C_i|H, K, C_{<i}). \quad (3)$$

This equation implies the dependencies in the process of example selection, which means that the examples selected first may influence the selection process afterwards. However, In practice, due to the high computational cost, it is not necessary to model the full dependency. Empirical results show that it is more efficient to model example retrieval as a Markov process, where the selection of current example only depends on target context and previously selected example:

$$\mathcal{P}_r(C|H, K) = \prod_{i=1}^n \mathcal{P}_r(C_i|H, K, C_{i-1}). \quad (4)$$

After examples are retrieved, we optionally re-rank them using similarity metrics, more details can be found in next subsection. Last, k demonstrations are placed in descending order according to their retrieval score and the target context is appended at the end to form the final prompt that is fed to LLMs. A prompt example is illustrated in Figure 3.

3.3 Diversified Example Retrieval Strategy

As mentioned earlier, the selection of examples is very important, and we need to ensure both the fidelity of the selected examples and a certain amount of diversity. In recommender systems,

there is a common task of multi-objective recommendation, such as ensuring both the relevance and the diversity of the retrieval. We drew inspiration from this (Sá et al., 2022) and design the **Diverse Example Retrieval** (DER) algorithm.

First, we retrieve N relevant examples $C_{ini} = \{C_1, C_2, \dots, C_N\} (N \gg n)$ based on query context q , where q is the combo of dialog history H and knowledge K . Notice that the initial K examples can be retrieved by any retrieval method, our goal is to find a diverse subset $C_{div} = \{C_1, C_2, \dots, C_n\}$. Next we find the example with the highest retrieval score and put it into a queue. We calculate the distance between the remaining examples and the example at the end of the current queue, and get the diverse score S according to Eq.(5). The final score is a linear combination of distance score and retrieval score controlled by hyper-parameter w :

$$S_{diverse}(C_i) = (1 - w) * distance(C_i, C_{last}) + w * s^{ret}(C_i, q) \quad (5)$$

where q denotes the query context, s^{ret} the retrieval score and C_{last} the last example in the queue. At last, we put the example with the highest diverse score at the end of queue. We repeat this process until there are n examples in the queue. In this way, the selected examples are both relevant to the input and distinct from the ones that have already been chosen. Algorithm 1 is a pseudo-code description of **DER**.

Algorithm 1: Diverse Example Retrieval

Data: Initial Retrieved Examples

$C_{ini} = \{C_1, C_2, \dots, C_N\} (N \gg n)$,
Empty Queue Q , Query Context q ,
Example Number n

Result: Diverse In-context Examples:

$C_{div} = \{C_1, C_2, \dots, C_n\}$

```

1 start;
2 Find example  $C_1$  with the highest retrieval
  score:  $Q.push\_back(C_1), C = C/C_1$ ;
3 while  $length(Q) < k$  do
4    $C_{temp} \leftarrow Q[-1]$ ;
5    $S_{div} \leftarrow dist(C_{temp}, C/C_{temp})$ ;
6    $S_{sim} \leftarrow sim(q, C/C_{temp})$ ;
7    $S \leftarrow (1 - w) * S_{div} + w * S_{sim}$ ;
8    $r \leftarrow \arg \max S$ ;
9    $Q.push\_back(C_r), C = C/C_r$ ;
10 end
11 return  $Q$ ;
```

4 Experimental Setup

We mainly experimented on **OpendialKG** using different retrieval strategies and different numbers of in-context examples. To ensure the universality of our method, we first run experiments on OpenAI’s GPT-3.5 (text-davinci-003) via APIs to verify the effectiveness and set hyper-parameters. Then we test our method on several LLMs. We set temperature to 0 in all our experiments to avoid the impact of randomness.

4.1 Dataset & Preprocessing

OpendialKG is currently the only public open-domain English dialog dataset that is annotated with **knowledge graph path** according to Yu et al. (2022). It also provides the textual form of knowledge corresponding to each knowledge triplet. A series of previous works have validated the effectiveness on this dataset (Ji et al., 2022; Dziri et al., 2021; Sarkar et al., 2022), so we choose to experiment on this dataset as well. We also experimented on **WOW**(Dinan et al., 2018) which only contains textual knowledge and yields similar results. Previous works filter OpendialKG by keeping dialogue samples that are annotated with at least one knowledge path. We do additional filtering to ensure that at least one knowledge path is actually **used** in the generated responses. We hope to select demonstrations that genuinely reflect how knowledge is leveraged and thus can serve as better examples.

4.2 Language Models

We explore the effectiveness of proposed framework primarily on GPT-3.5(text-davinci-003) (Ouyang et al., 2022) which are served as black-box language models through APIs¹. The currently most advanced LLMs such as GPT-4 (OpenAI, 2023) is included in our test as well. We also experimented on open-source Vicuna-13B² and GPT-J (Wang and Komatsuzaki, 2021). The selection of black-box language models is not the primary focus of this study; rather, we seek to investigate IKA’s universality.

4.3 Retrieval Methods for IKA

Sparse Retrieval

Sparse retrieval techniques are a class of traditional methods. Common sparse retrieval methods in-

¹<https://platform.openai.com/>

²<https://huggingface.co/TheBloke/wizard-vicuna-13B-HF>

Model	#Parameters	Open Source
GPT-2 (2019)	1.5B	✓
GPT-J (2021)	6B	✓
Vicuna(2023)	13B	✓
GPT-3.5(2023)	175B	✗
GPT-4 (2023)	<i>unknown</i>	✗

Table 1: A wide variety of large language models with parameters ranging from 1.5B to 175B are chosen in our experiments.

clude **TF-IDF** and **BM25** (Robertson and Walker, 1994). By arranging the documents into an inverted index, where each different word has an inverted list that contains information about the articles it appears in, this type of retrieval model can swiftly process queries. However, they often fall short of matching related words (Metzler and Croft, 2005) that are similar in meaning. Recent works have proposed to use contextualized representation to leverage the power of deep learning language models (Gao et al., 2021).

Dense Retrieval

In dense retrieval, queries and documents are often directly encoded by large neural models into single or multiple vectors, which allow for efficient *dense* retrieval based on simple similarity function such as dot-product or ANN. These vectors compress high dimensional semantic information.

Four types of dense retrieval are implemented in our experiments, the first three are bi-directional contextual language models (BERT (Devlin et al., 2018), RoBERTa (Liu et al., 2019), BART (Lewis et al., 2019)) using [CLS] embedding as the final input representation. The same encoder is used for both query and document. We also implement TCT-ColBERT (Wang et al., 2022) using index service provided by Pyserini³ and FAISS⁴ libraries.

Dense-Sparse Hybrid

The hybrid method can capture both lexical similarity and high-level semantic relevance. We further show that combining dense retrieval with sparse retrieval can improve performance. Following Lin and Ma (2021), TCT-ColBERT and Uni-COIL are chosen as dense retriever and sparse retriever in our hybrid setting. Through linear combination of scores, we adjust them to have the same order of magnitude.

³<https://github.com/castorini/pyserini/>

⁴<https://github.com/facebookresearch/faiss>

Diverse Example Retrieval

DER is implemented as described in 3.3. Note that the initial example set can be retrieved by any method, for simplicity we choose dense and hybrid retrieval described above. For distance measure, we choose RoBERTa (Liu et al., 2019) as the text encoder to obtain the dense vector representation and calculate the cosine distance between examples. The embeddings produced by RoBERTa capture semantic similarities between words and sentences, which has been proved to be beneficial for information retrieval tasks.

4.4 Baselines

We compare following strong baselines to demonstrate the efficacy of our framework. **RHO** (Ji et al., 2022) fine-tunes BART (Lewis et al., 2019) and GPT-2 (Radford et al., 2019), introduces local and global knowledge grounding techniques with an ad hoc re-ranking procedure. They report SOTA results on **OpendialKG** dataset. Other strong baselines are Sarkar et al. (2022) and Kang et al. (2022).

4.5 Evaluation Metrics

General Generation Evaluation

We conduct automated evaluation to measure the general generation quality and knowledge faithfulness of responses. Traditional word-overlap based metrics such as **BLEU**(Papineni et al., 2002) and **ROGUE-L**(Lin, 2004) are adopted. Meanwhile, some pre-trained models also exhibit promising results in term of evaluating generation informativeness, fluency and relevance, one among them is **BARTScore**(Yuan et al., 2021), which formulates evaluating text as a generation task and achieves better performance than compared metrics.

Faithful Generation Evaluation

For evaluating faithfulness, we consider **Entity Coverage** and **FeQA**(Durmus et al., 2020). Ji et al. (2022) argue that entities in generated responses should be covered by ones appear in dialog history and knowledge. Based on the entity collection of Freebase(Bollacker et al., 2008), we use exact match to extract named entities and calculate **Entity Precision, Recall and F1** score. In prior works (Ji et al., 2022; Dziri et al., 2021), question answering based metrics for faithfulness like **FeQA** are applied. FeQA first generates QA pairs from summary and then extracts answers from the document. We concatenate dialog history and knowledge as

Model	BLEU4 \uparrow	ROUGE-L \uparrow	BS \uparrow	Entity Coverage% \uparrow			FeQA \uparrow	Avg Len
				Pre	Recall	F1		
GPT-2 0-shot	28.51	23.44	4.01	80.67	40.40	53.84	41.65	11.88
GPT-J 0-shot	39.37	29.99	4.02	87.70	36.28	51.33	44.27	13.29
Vicuna 0-shot	37.65	28.60	5.02	59.86	56.41	58.09	24.04	26.10
GPT-3.5 0-shot	46.38	34.86	5.37	76.69	69.74	73.05	43.74	16.12
NPH* (2021)	10.41*	29.93*	-	95.61*	33.39*	53.96*	-	-
RHO (2022)	39.62	37.37	4.89	81.13	47.57	59.97	44.97	9.76
IKA+GPT-2	27.14	20.92	3.65	53.15	27.19	35.98	23.76	12.36
IKA+GPT-J	40.45	31.00	5.04	57.86	40.70	47.79	31.02	16.45
IKA+Vicuna	50.28	41.14	7.03	65.27	58.63	61.77	31.43	17.63
IKA+GPT-3.5	58.11	47.09	10.90	79.12	77.41	78.26	44.67	17.08
IKA+GPT-4	49.44	39.45	7.12	73.33	77.73	75.47	37.99	21.07
Gold Res.	100	100	47.38	100	100	100	49.73	17.75

Table 2: Experimental results on **OpendialKG** under different settings. For experiments with IKA, we use hybrid retrieval described in 4.3, the number of examples is set to 3. *The results of NPH are reported in (Ji et al., 2022); the results of RHO(Ji et al., 2022) are calculated from their publicly available generated results⁵. \uparrow BS stands for BARTScore; Gold Res. stands for ground truth response.

the document and response as the summary to measure whether the generated response is faithful to the original context(Dziri et al., 2021).

5 Results and Analysis

The experimental results on **OpendialKG** are summarized in Table 2 and Table 3. The performance of IKA is compared to previous training-based methods and zero-shot baselines.

5.1 Main Results

IKA greatly improves knowledge grounded dialogue generation quality. Table 2 summarizes the results of experiments on previous SOTA model and LLMs. The top four rows report the zero-shot performance of different LLMs, and GPT-3.5 achieves the best generation performance among them, 46.38 in BLEU4, 34.86 in ROUGE-L and 5.37 in BARTScore, which is in line with recent studies (Hendy et al., 2023). We also report the average length of generated outputs. Vicuna generates the longest 26.10 words under 0-shot setting, which results in the lowest FeQA score. It seems that Vicuna has the tendency to produce redundant nonsense. However when we combine Vicuna with IKA, the average length of generated response significantly decreases while all evaluation metrics increase. Similar improvements are observed across different backbone LLMs except for GPT-2. One possible explanation may be the lack of ICL ability for smaller language models like GPT-2.

Row 5 and Row 6 in Table 2 correspond to previous SOTA. The performance of our framework when paired with various LLMs is presented in the next five lines. Our framework outperforms SOTA method (Ji et al., 2022) on general generation metrics and faithful generation metrics, with a significant rise of **46.67%** in BLEU4, **26.01%** in ROUGE-L, **122.90%** in BARTScore and **30.50%** in Entity Coverage F1. In order to keep the results comparable, we filter and split our training and test set so that they are both subsets of Ji et al. (2022). We only evaluate on the common test samples in Table 2.

The retrieval method is vital to the performance of IKA. In Table 3, we report the results of several types of retrieval methods. Here we fix the retrieved example number to 3. The first row of Table 3 is random baseline. Although our reference dataset has been filtered in advance which means even random sampling can retrieve relatively high quality examples, the improvement obtained is still insignificant compared to the zero-shot baseline reported in Table 2. If we choose a proper retrieval method such as BM-25 (Robertson and Walker, 1994) or TCT-ColBERT (Wang et al., 2022) the performance will boost. The hybrid retrieval method achieves the highest performance in BLEU4, ROUGE-L and BARTScore, with the rise of **18.43%**, **27.75%** and **69.78%** respectively compared to random baseline.

Our diverse strategy improves models' faith-

Retrieval Methods		BLEU4 \uparrow	ROUGE-L \uparrow	BS \uparrow	Entity Coverage% \uparrow			FeQA \uparrow
					Pre.	Recall	F1	
Sparse	Random	47.86	36.04	5.99	80.46	71.44	75.68	43.01
	BM-25	51.98	41.20	7.59	80.46	73.40	76.77	43.71
	Uni-COIL	56.60	45.97	9.97	80.85	75.06	77.85	44.15
Dense	BERT	55.63	39.42	7.14	81.09	75.36	77.79	43.94
	RoBERTa	46.42	35.74	5.66	82.03	69.27	75.11	47.65
	BART	48.49	37.03	6.20	81.13	70.20	75.27	46.32
	TCT-CBT	50.67	39.06	6.67	82.03	73.15	77.33	44.12
Hybrid	Hybrid	56.68	46.14	10.17	81.32	75.53	78.32	44.67
Diverse	U-C div	56.17	45.61	9.99	81.14	75.58	78.26	44.80
	Hybrid div	52.89	42.34	7.85	84.47	74.21	79.01	48.08

Table 3: Comparison of different retrieval methods. Only top-3 retrieval results are used in the final prompts. Random sampling serves as the baseline. Among all retrieval methods the hybrid method achieves the highest scores on general quality metrics, whereas DER further improves faithfulness metrics while sacrificing generation metrics.

#EX	Triplet		Text	
	BS	EC-F1	BS	EC-F1
1	6.48	74.97	5.99	74.23
3	10.90	77.16	9.99	75.91
5	13.16	77.62	12.52	77.50
10	15.12	77.25	14.38	77.82

Table 4: Comparison of knowledge representation.

fulness generation ability. In Section 3.3 we propose the diverse strategy for ICL example selection. Since it involves the trade-off between relevance and diversity controlled by the hyper-parameter w , additional hyper-parameter search is required in practice. Due to resource constraint we empirically set a value for w based on performance on dev set, and it is able to achieve the highest Entity Coverage F1 at **79.01** and FeQA at **48.08** with a slight drop on general quality metrics. A HP search for coefficients may further boost the performance of DER.

5.2 Analysis

In this section, we give some analysis on different aspects of our IKA framework.

On the High Scores of Generation Metrics

The BLEU and ROUGE scores in Table 2 and 3 may seem extraordinary high for a text generation task. The task of knowledge grounded dialog generation focuses on the usage of knowledge. Its task structure inherently leads to relatively fixed outputs, as the majority of the information is derived from the input knowledge. Having a high BLEU/ROUGE score for such a task is quite rea-

sonable, since these metrics only measure word-overlapping in discrete string space. In summation, metrics to explicitly measure how well models or frameworks can generate faithfully are needed.

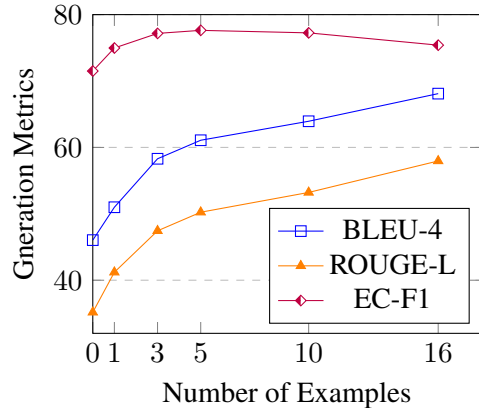


Figure 4: Generation metrics for IKA under different number of examples.

On the Impact of the Number of Examples

According to Brown et al. (2020), the number of demonstrations is an important factor in ICL. To test the scalability of IKA and also keep the constructed prompt within context window size, we experiment the number of examples from 0 to 16. Figure 5.2 illustrates the results. As the number grows, IKA generates more high quality response; but the EC-F1 metric rises and then falls, which means there might be a trade-off between faithfulness and the generation quality. The more examples provided, the better LLMs can mimic conversation style which contributes to the improvements in evaluation metrics.

Ret.	#EX	BLEU4	ROUGE-L	BS
None	0	13.99	9.39	2.92
Rand.	3	58.09	58.62	23.15
BM25	3	60.35	61.09	24.78

Table 5: Results of IKA+GPT3.5(text-davinci-003) on Wizard-of-Wikipedia(Dinan et al., 2018) unseen split results.

On the Choice of Knowledge Representation

We compare the performance of IKA given different forms of knowledge including knowledge graphs and **texts**. Results on OpendialKG are presented in Table 4. Surprisingly the knowledge triplet is almost always better no matter how many examples are presented. One possible reason is that the knowledge triplet is more suitable for example retrieval given their succinct triplet form, while textual knowledge may provide redundant information. Besides, the structured form is more compact which passes the most essential knowledge to LLMs. Results on Wizard-of-Wikipedia (Dinan et al., 2018) are summarized in Table 5, where only textual knowledge is provided. Under 3-example setup, we compare random retrieval and BM25 retrieval. On unseen test split of WoW, BLEU and ROUGE-L increase from 58.09 to 60.35 and 58.62 to 61.09 respectively, BARTScore increases from 23.15 to 24.78. These results demonstrate the universality of our framework across different forms and areas of knowledge.

6 Conclusion

In this paper, we explore the strategy of adopting in-context learning for knowledge grounded dialog generation. We propose a plug-and-play retrieval based framework **IKA** that can be easily integrated with LLMs. Our framework **significantly** outperforms strong baselines and previous SOTAs without additional parameters update. We explicitly model the dependency between ICL examples and design a diversification strategy that further improves performance. Experiments demonstrate the effectiveness and generalization of our framework. Our results also provide the evidence for ICL’s potentials in knowledge-intensive tasks.

Limitations

In this work, we do not study the knowledge selection process which is also important to knowledge grounded generation. Following previous works,

we assume that the gold relevant knowledge is provided in target context. How LLMs integrate knowledge is also under-studied. Due to text window size constraints, we are unable to obtain results for more examples. Last, we do not perform human evaluation to analyze different types of faithfulness errors in our generated results. We leave these open questions for future work.

Ethics Statement

Our work complies with the ACL Ethics Policy. All datasets and models are publicly accessible except for OpenAI’s text-davinci-003 and GPT-4. We have not identified any significant ethical considerations associated with our work. We believe our findings can help reducing LLMs’ hallucinations.

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References

- Ekin Akyürek, Dale Schuurmans, Jacob Andreas, Tengyu Ma, and Denny Zhou. 2022. What learning algorithm is in-context learning? investigations with linear models. *arXiv preprint arXiv:2211.15661*.
- Ebtesam Almazrouei, Hamza Alobeidli, Abdulaziz Alshamsi, Alessandro Cappelli, Ruxandra Cojocaru, Merouane Debbah, Etienne Goffinet, Daniel Heslow, Julien Launay, Quentin Malartic, Badreddine Noune, Baptiste Pannier, and Guilherme Penedo. 2023. Falcon-40B: an open large language model with state-of-the-art performance.
- Kurt Bollacker, Colin Evans, Praveen Paritosh, Tim Sturge, and Jamie Taylor. 2008. Freebase: a collaboratively created graph database for structuring human knowledge. In *Proceedings of the 2008 ACM SIGMOD international conference on Management of data*, pages 1247–1250.
- Tom Brown, Benjamin Mann, Nick Ryder, Melanie Subbiah, Jared D Kaplan, Prafulla Dhariwal, Arvind Neelakantan, Pranav Shyam, Girish Sastry, Amanda Askell, et al. 2020. Language models are few-shot learners. *Advances in neural information processing systems*, 33:1877–1901.
- Jacob Devlin, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2018. Bert: Pre-training of deep

- bidirectional transformers for language understanding. *arXiv preprint arXiv:1810.04805*.
- Emily Dinan, Stephen Roller, Kurt Shuster, Angela Fan, Michael Auli, and Jason Weston. 2018. Wizard of wikipedia: Knowledge-powered conversational agents. *arXiv preprint arXiv:1811.01241*.
- Esin Durmus, He He, and Mona Diab. 2020. Feqa: A question answering evaluation framework for faithfulness assessment in abstractive summarization. *arXiv preprint arXiv:2005.03754*.
- Nouha Dziri, Ehsan Kamaloo, Sivan Milton, Osmar Zaiane, Mo Yu, Edoardo M Ponti, and Siva Reddy. 2022a. Faithdial: A faithful benchmark for information-seeking dialogue. *Transactions of the Association for Computational Linguistics*, 10:1473–1490.
- Nouha Dziri, Andrea Madotto, Osmar Zaiane, and Avishek Joey Bose. 2021. Neural path hunter: Reducing hallucination in dialogue systems via path grounding. *arXiv preprint arXiv:2104.08455*.
- Nouha Dziri, Sivan Milton, Mo Yu, Osmar Zaiane, and Siva Reddy. 2022b. On the origin of hallucinations in conversational models: Is it the datasets or the models? *arXiv preprint arXiv:2204.07931*.
- Linnea Evanson, Yair Lakretz, and Jean-Rémi King. 2023. Language acquisition: do children and language models follow similar learning stages? *arXiv preprint arXiv:2306.03586*.
- Luyu Gao, Zhuyun Dai, and Jamie Callan. 2021. Coil: Revisit exact lexical match in information retrieval with contextualized inverted list. *arXiv preprint arXiv:2104.07186*.
- He He, Anusha Balakrishnan, Mihail Eric, and Percy Liang. 2017. Learning symmetric collaborative dialogue agents with dynamic knowledge graph embeddings. *arXiv preprint arXiv:1704.07130*.
- Amr Hendy, Mohamed Abdelrehim, Amr Sharaf, Vikas Raunak, Mohamed Gabr, Hitokazu Matsushita, Young Jin Kim, Mohamed Afify, and Hany Hassan Awadalla. 2023. How good are gpt models at machine translation? a comprehensive evaluation. *arXiv preprint arXiv:2302.09210*.
- Zhiting Hu and Li Erran Li. 2021. A causal lens for controllable text generation. *Advances in Neural Information Processing Systems*, 34:24941–24955.
- Yichong Huang, Xiachong Feng, Xiaocheng Feng, and Bing Qin. 2021. The factual inconsistency problem in abstractive text summarization: A survey. *arXiv preprint arXiv:2104.14839*.
- Ziwei Ji, Nayeon Lee, Rita Frieske, Tiezheng Yu, Dan Su, Yan Xu, Etsuko Ishii, Ye Jin Bang, Andrea Madotto, and Pascale Fung. 2023. Survey of hallucination in natural language generation. *ACM Computing Surveys*, 55(12):1–38.
- Ziwei Ji, Zihan Liu, Nayeon Lee, Tiezheng Yu, Bryan Wilie, Min Zeng, and Pascale Fung. 2022. Rho : Reducing hallucination in open-domain dialogues with knowledge grounding. *arXiv preprint arXiv:2212.01588*.
- Minki Kang, Jin Myung Kwak, Jinheon Baek, and Sung Ju Hwang. 2022. Knowledge-consistent dialogue generation with knowledge graphs.
- Katherine Lee, Orhan Firat, Ashish Agarwal, Clara Fanjiang, and David Sussillo. 2018. Hallucinations in neural machine translation.
- Mike Lewis, Yinhan Liu, Naman Goyal, Marjan Ghazvininejad, Abdelrahman Mohamed, Omer Levy, Ves Stoyanov, and Luke Zettlemoyer. 2019. Bart: Denoising sequence-to-sequence pre-training for natural language generation, translation, and comprehension. *arXiv preprint arXiv:1910.13461*.
- Chin-Yew Lin. 2004. Rouge: A package for automatic evaluation of summaries. In *Text summarization branches out*, pages 74–81.
- Jimmy Lin and Xueguang Ma. 2021. A few brief notes on deepimpact, coil, and a conceptual framework for information retrieval techniques. *arXiv preprint arXiv:2106.14807*.
- Jiachang Liu, Dinghan Shen, Yizhe Zhang, Bill Dolan, Lawrence Carin, and Weizhu Chen. 2021. What makes good in-context examples for gpt-3? *arXiv preprint arXiv:2101.06804*.
- Yinhan Liu, Myle Ott, Naman Goyal, Jingfei Du, Mandar Joshi, Danqi Chen, Omer Levy, Mike Lewis, Luke Zettlemoyer, and Veselin Stoyanov. 2019. Roberta: A robustly optimized bert pretraining approach. *arXiv preprint arXiv:1907.11692*.
- Donald Metzler and W Bruce Croft. 2005. A markov random field model for term dependencies. In *Proceedings of the 28th annual international ACM SIGIR conference on Research and development in information retrieval*, pages 472–479.
- Sabrina J Mielke, Arthur Szlam, Emily Dinan, and Y-Lan Boureau. 2022. Reducing conversational agents’ overconfidence through linguistic calibration. *Transactions of the Association for Computational Linguistics*, 10:857–872.
- Sewon Min, Xinxin Lyu, Ari Holtzman, Mikel Artetxe, Mike Lewis, Hannaneh Hajishirzi, and Luke Zettlemoyer. 2022. Rethinking the role of demonstrations: What makes in-context learning work? *arXiv preprint arXiv:2202.12837*.
- Seungwhan Moon, Pararth Shah, Anuj Kumar, and Rajen Subba. 2019. Opendialkg: Explainable conversational reasoning with attention-based walks over knowledge graphs. In *Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics*, pages 845–854.

- Catherine Olsson, Nelson Elhage, Neel Nanda, Nicholas Joseph, Nova DasSarma, Tom Henighan, Ben Mann, Amanda Askell, Yuntao Bai, Anna Chen, et al. 2022. In-context learning and induction heads. *arXiv preprint arXiv:2209.11895*.
- OpenAI. 2023. [Gpt-4 technical report](#).
- Long Ouyang, Jeffrey Wu, Xu Jiang, Diogo Almeida, Carroll Wainwright, Pamela Mishkin, Chong Zhang, Sandhini Agarwal, Katarina Slama, Alex Ray, et al. 2022. Training language models to follow instructions with human feedback. *Advances in Neural Information Processing Systems*, 35:27730–27744.
- Kishore Papineni, Salim Roukos, Todd Ward, and Wei-Jing Zhu. 2002. Bleu: a method for automatic evaluation of machine translation. In *Proceedings of the 40th annual meeting of the Association for Computational Linguistics*, pages 311–318.
- Alec Radford, Jeffrey Wu, Rewon Child, David Luan, Dario Amodei, Ilya Sutskever, et al. 2019. Language models are unsupervised multitask learners. *OpenAI blog*, 1(8):9.
- Stephen E Robertson and Steve Walker. 1994. Some simple effective approximations to the 2-poisson model for probabilistic weighted retrieval. In *SIGIR'94: Proceedings of the Seventeenth Annual International ACM-SIGIR Conference on Research and Development in Information Retrieval, organised by Dublin City University*, pages 232–241. Springer.
- João Sá, Vanessa Queiroz Marinho, Ana Rita Magalhães, Tiago Lacerda, and Diogo Goncalves. 2022. Diversity vs relevance: A practical multi-objective study in luxury fashion recommendations. In *Proceedings of the 45th International ACM SIGIR Conference on Research and Development in Information Retrieval*, pages 2405–2409.
- Rajdeep Sarkar, Mihael Arcan, and John Philip McCrae. 2022. Kg-cruse: Recurrent walks over knowledge graph for explainable conversation reasoning using semantic embeddings. In *Proceedings of the 4th Workshop on NLP for Conversational AI*, pages 98–107.
- Kurt Shuster, Spencer Poff, Moya Chen, Douwe Kiela, and Jason Weston. 2021. Retrieval augmentation reduces hallucination in conversation. *arXiv preprint arXiv:2104.07567*.
- Romal Thoppilan, Daniel De Freitas, Jamie Hall, Noam Shazeer, Apoorv Kulshreshtha, Heng-Tze Cheng, Alicia Jin, Taylor Bos, Leslie Baker, Yu Du, et al. 2022. Lamda: Language models for dialog applications. *arXiv preprint arXiv:2201.08239*.
- Nitasha Tiku. 2022. The google engineer who thinks the company’s ai has come to life. *The Washington Post*, 11.
- Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. Attention is all you need. *Advances in neural information processing systems*, 30.
- Ben Wang and Aran Komatsuzaki. 2021. GPT-J-6B: A 6 Billion Parameter Autoregressive Language Model. <https://github.com/kingoflolz/mesh-transformer-jax>.
- Xiao Wang, Sean MacAvaney, Craig Macdonald, and Iadh Ounis. 2022. An inspection of the reproducibility and replicability of tct-colbert. In *Proceedings of the 45th International ACM SIGIR Conference on Research and Development in Information Retrieval*, pages 2790–2800.
- Xinyi Wang, Wanrong Zhu, and William Yang Wang. 2023. Large language models are implicitly topic models: Explaining and finding good demonstrations for in-context learning. *arXiv preprint arXiv:2301.11916*.
- Zequi Wu, Michel Galley, Chris Brockett, Yizhe Zhang, Xiang Gao, Chris Quirk, Rik Koncel-Kedziorski, Jianfeng Gao, Hannaneh Hajishirzi, Mari Ostendorf, et al. 2021. A controllable model of grounded response generation. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 35, pages 14085–14093.
- Yan Xu, Etsuko Ishii, Samuel Cahyawijaya, Zihan Liu, Genta Indra Winata, Andrea Madotto, Dan Su, and Pascale Fung. 2021. Retrieval-free knowledge-grounded dialogue response generation with adapters. *arXiv preprint arXiv:2105.06232*.
- Wenhao Yu, Chenguang Zhu, Zaitang Li, Zhiting Hu, Qingyun Wang, Heng Ji, and Meng Jiang. 2022. A survey of knowledge-enhanced text generation. *ACM Computing Surveys*, 54(11s):1–38.
- Weizhe Yuan, Graham Neubig, and Pengfei Liu. 2021. Bartscore: Evaluating generated text as text generation. *Advances in Neural Information Processing Systems*, 34:27263–27277.
- Houyu Zhang, Zhenghao Liu, Chenyan Xiong, and Zhiyuan Liu. 2019. Grounded conversation generation as guided traverses in commonsense knowledge graphs. *arXiv preprint arXiv:1911.02707*.
- Hao Zhou, Minlie Huang, Yong Liu, Wei Chen, and Xiaoyan Zhu. 2021. Earl: Informative knowledge-grounded conversation generation with entity-agnostic representation learning. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 2383–2395.