



A Survey on Hallucination in Large Language Models: Principles, Taxonomy, Challenges, and Open Questions

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Abstract

The emergence of large language models (LLMs) has marked a significant breakthrough in natural language processing (NLP), leading to remarkable advancements in text understanding and generation. Nevertheless, alongside these strides, LLMs exhibit a critical tendency to produce hallucinations, resulting in content that is inconsistent with real-world facts or user inputs. This phenomenon poses substantial challenges to their practical deployment and raises concerns over the reliability of LLMs in real-world scenarios, which attracts increasing attention to detect and mitigate these hallucinations. In this survey, we aim to provide a thorough and in-depth overview of recent advances in the field of LLM hallucinations. We begin with an innovative taxonomy of LLM hallucinations, then delve into the factors contributing to hallucinations. Subsequently, we present a comprehensive overview of hallucination detection methods and benchmarks. Additionally, representative approaches designed to mitigate hallucinations are introduced accordingly. Finally, we analyze the challenges that highlight the current limitations and formulate open questions, aiming to delineate pathways for future research on hallucinations in LLMs. ¹

reasoning (Wei et al., 2022; Kojima et al., 2022; Qiao et al., 2022; Yu et al., 2023a; Chu et al., 2023). Nevertheless, in tandem with the rapid advancement in LLMs, there’s a concerning trend where they exhibit an inclination to generate hallucinations (Bang et al., 2023; Guerreiro et al., 2023b), resulting in seemingly plausible yet factually unsupported content.

The current definition of hallucinations aligns with prior research (Ji et al., 2023a), characterizing them as generated content that is nonsensical or unfaithful to the provided source content. These hallucinations are further categorized into *intrinsic hallucination* and *extrinsic hallucination* types, depending on the contradiction with the source content. While this category is shared among various natural language generation (NLG) tasks, task-specific variations do exist. As LLMs are remarkably versatile and excel across different NLG tasks (Bubeck et al., 2023; Bang et al., 2023), particularly in open-domain applications, their remarkable versatility amplifies the potential for hallucinations compared to *task-specific models*. In LLMs, the scope of hallucination encompasses a broader and more comprehensive concept, primarily *centering on factual errors*. In light of the evolution of the LLM era, there arises a need to adjust the existing hallucination taxonomy, enhancing its applicability and adaptability.

In this survey, we have redefined the taxonomy of hallucination, offering a more tailored framework for LLM applications. We categorize hallucination into two main groups: *factuality hallucination* and *faithfulness hallucination*. *Factuality hallucination* emphasizes the discrepancy between generated content and verifiable real-world facts, typically manifesting as factual inconsistency or fabrication. For example, as in Fig. 1(a), when queried about the first person to walk on the moon,

1 Introduction

Recently, the emergence of large language models (LLMs) (OpenAI, 2022; Google, 2023; Touvron et al., 2023; Penedo et al., 2023; Zhao et al., 2023b) has ushered in a paradigm shift in natural language processing (NLP), achieving unprecedented progress in language understanding (Hendrycks et al., 2021; Huang et al., 2023c), generation (Zhang et al., 2023f; Zhu et al., 2023b) and

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¹Resources are available at: <https://github.com/LuckyyySTA/Awesome-LLM-hallucination>

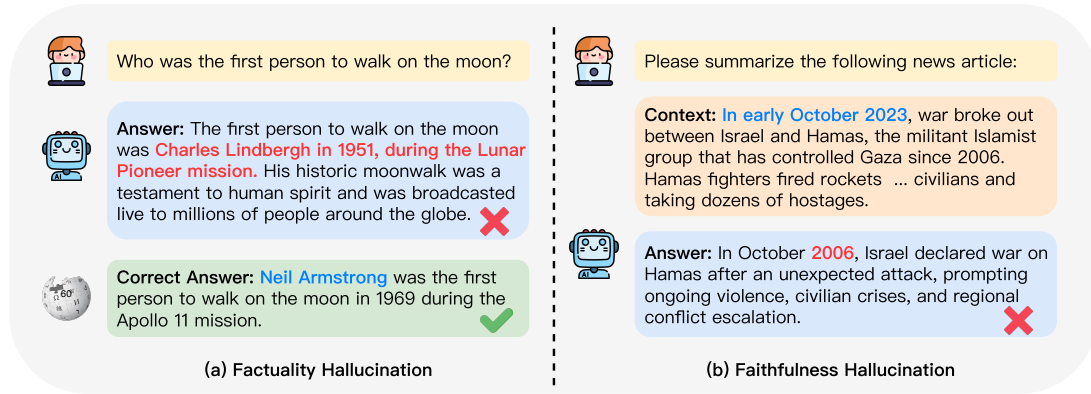


Figure 1: An intuitive example of LLM hallucination.

the model might assertively claim it was Charles Lindbergh in 1951. While the truth is that Neil Armstrong was the first individual to walk on the moon in 1969 during the Apollo 11 mission. On the other hand, *faithfulness hallucination* refers to the divergence of generated content from user instructions or the context provided by the input, as well as self-consistency within generated content. As illustrated in Figure 1(b), when asked to summarize a news article, the model inaccurately generated the actual event date of the conflict between Israel and Hamas from October 2023 to October 2006. Regarding factuality, we further divide it based on the presence of verifiable sources into two subcategories: factual inconsistency and factual fabrication. For faithfulness, we emphasize addressing inconsistency from the user’s perspective, categorizing it into instruction inconsistency, context inconsistency, and logical inconsistency, thus aligning it better with the current usage of LLMs.

As for the underlying causes of hallucinations, while studied in the context of NLG tasks, present unique challenges in cutting-edge LLMs that are worthy of an in-depth investigation. Our in-depth analysis specifically targets the unique origins of hallucinations in LLMs, spanning a spectrum of contributing factors from *data, and training, to the inference stage*. Within this framework, we pinpoint potential data-related causes such as flawed sources and suboptimal utilization, inferior training strategies that may induce hallucinations during pre-training and alignment, and those stemming from the stochastic nature of decoding strategies and imperfect representations during the inference process. Furthermore, we comprehensively outline a variety of effective detection methods specifically devised for detecting hallucinations in LLMs, as

well as an exhaustive overview of benchmarks related to LLM hallucinations, serving as appropriate testbeds to assess the extent of hallucinations generated by LLMs and the efficacy of detection methods. Moreover, we detail comprehensive strategies tailored to mitigate the identified causes of hallucinations.

Through this comprehensive survey, we aim to contribute to the advancement of the field of LLMs and provide valuable insights that deepen the understanding of the opportunities and challenges associated with hallucinations in LLMs. This exploration not only enhances our understanding of the limitations of current LLMs but also provides essential guidance for future research and the development of more robust and trustworthy LLMs.

Comparing with Existing Surveys. As the push for reliable generative AI intensifies, LLM hallucination stands out as a major challenge, leading to numerous surveys on its recent advancements (Ji et al., 2023a; Rawte et al., 2023; Liu et al., 2023h; Zhang et al., 2023g; Wang et al., 2023c). While these works have probed into LLM hallucination from diverse angles and offered valuable insights, it is imperative to distinguish the unique aspects and comprehensive nature of our present survey. (Ji et al., 2023a) primarily sheds light on hallucinations in pre-trained language models within the realm of NLG tasks, leaving LLMs outside their discussion purview. (Liu et al., 2023h) discusses the trustworthiness of LLMs from a broader perspective, while (Wang et al., 2023c) delves deeply into LLM factuality. In contrast, our survey zeroes in on a subset of challenges in LLM trustworthiness, covering aspects of factuality and further broadening the discourse to include faithfulness-related hallucinations. To the best of our knowledge, the work most aligned with our survey is

(Zhang et al., 2023g), which outlines taxonomies of LLM hallucination phenomena, evaluation benchmarks, and mitigation strategies. Nevertheless, our survey distinguishes itself both in terms of its taxonomy and organizational structure. We present a layered and granular classification of hallucinations. Structurally, we dissect the causes of LLM hallucination by tracing back to the capabilities of LLMs. More pertinently, our mitigation strategies are intricately linked with the underlying causes, ensuring a cohesive and targeted approach.

Organization of this Survey. In this paper, we present a comprehensive survey of the latest developments regarding hallucinations in LLMs. We commence by defining LLMs and constructing a taxonomy of hallucinations within this context (§2). Subsequently, we analyze the factors contributing to hallucinations in LLMs in depth (§3), followed by an examination of various methodologies and benchmarks employed for the reliable detection of hallucinations in LLMs (§4). We then detail a spectrum of approaches designed to mitigate hallucinations in LLMs (§5). Concluding, we delve into the challenges and open questions that frame the current limitations and future prospects of this field, offering insights and delineating potential pathways for forthcoming research (§6).

2 Definitions

For the sake of a comprehensive understanding of hallucinations in LLMs, we commence with a succinct introduction to LLMs (§2.1), delineating the scope of this survey. Subsequently, we delve into the training process of LLMs (§2.2), as a thorough understanding of the underlying training mechanisms contributes significantly to elucidating the origins of hallucinations. Lastly, we expound upon the concept of hallucinations (§2.3) in LLMs, further categorizing it into two distinct types.

2.1 Large Language Models

Before delving into the causes of hallucination, we first introduce the concept of LLMs. Typically, LLMs refer to a series of general-purpose models that leverage the Transformer-based language model architecture and undergo extensive training on massive textual corpora with notable examples including GPT-3 (Brown et al., 2020), PaLM (Chowdhery et al., 2023), Galactica (Taylor et al., 2022) LLaMA (Touvron et al., 2023) and GPT-4 (OpenAI, 2023). By scaling the amount of data and

model capacity, LLMs raise amazing emergent abilities, typically including In-Context Learning (ICL) (Brown et al., 2020), Chain-of-Thought prompting (Wei et al., 2022) and instruction following (Peng et al., 2023).

2.2 Training Stages of Large Language Models

The attributes and behaviors of LLMs are deeply intertwined with their training processes. LLMs undergo three primary training stages: pre-training, supervised fine-tuning (SFT), and reinforcement learning from human feedback (RLHF). Analyzing these stages provides insight into hallucination origins in LLMs, as each stage equips the model with specific capabilities.

Pre-training. Pre-training is generally considered a crucial stage for LLM to acquire knowledge and skills (Zhou et al., 2023a). Language models, during pre-training, aim to predict the next token in a sequence autoregressively. Through self-supervised training on extensive textual corpora, the model acquires knowledge of language syntax, world knowledge, and reasoning abilities, providing a robust foundation for subsequent fine-tuning tasks. Besides, recent research (Sutskever, 2023; Delétang et al., 2023) suggests that predicting subsequent words is akin to losslessly compressing significant information. The essence of language models lies in predicting the probability distribution for upcoming words. Accurate predictions indicate a profound grasp of knowledge, translating to a nuanced understanding of the world.

Supervised Fine-Tuning. While LLMs acquire substantial knowledge and capabilities during the pre-training stage, it’s crucial to recognize that pre-training primarily optimizes for completion. Consequently, pre-trained LLMs fundamentally served as completion machines, which can lead to a misalignment between the next-word prediction objective of LLMs and the user’s objective of obtaining desired responses. To bridge this gap, SFT (Zhang et al., 2023d) has been introduced, which involves further training LLMs using a meticulously annotated set of (instruction, response) pairs, resulting in enhanced capabilities and improved controllability of LLMs. Furthermore, recent studies (Chung et al., 2022; Iyer et al., 2022) have confirmed the effectiveness of supervised fine-tuning to achieve exceptional performance on unseen tasks, showcasing their remarkable generalization abilities.

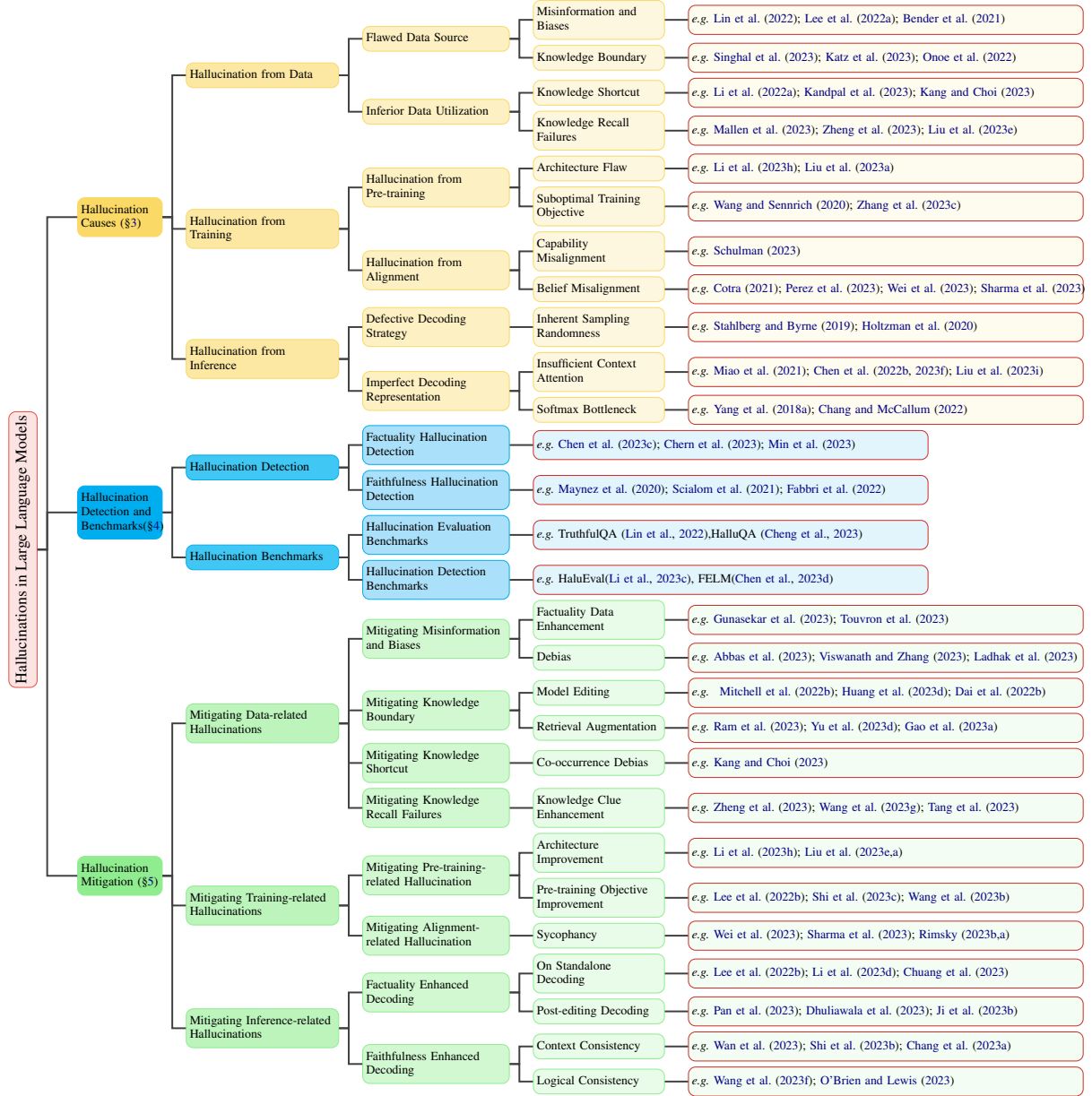


Figure 2: The main content flow and categorization of this survey.

Reinforcement Learning from Human Feedback. While the SFT process successfully enables LLMs to follow user instructions, there is still room for them to better align with human preferences. Among various methods that utilize human feedback, RLHF stands out as an institute solution for aligning with human preferences through reinforcement learning (Christiano et al., 2017; Stiennon et al., 2020; Ouyang et al., 2022). Typically, RLHF employs a *preference model* (Bradley and Terry, 1952) trained to predict preference rankings given a prompt alongside a pair of human-labeled responses. To align with human preferences, RLHF optimizes the LLM to generate outputs that maximize the reward provided by the trained preference model, typically employing a reinforcement learning algorithm, such as Proximal Policy Optimization (PPO)(Schulman et al., 2017). Such integration of human feedback into the training loop has proven effective in enhancing the alignment of LLMs, guiding them toward producing high-quality and harmless responses.

2.3 Hallucinations in Large Language Models

The concept of hallucination traces its roots to the fields of pathology and psychology and is defined as *the perception of an entity or event that is absent in reality* (Macpherson and Platchias, 2013). Within the realm of NLP, hallucination is typically referred to as a phenomenon in which the generated content appears nonsensical or unfaithful to the provided source content (Filippova, 2020; Maynez et al., 2020). This concept bears a loose resemblance to the phenomenon of hallucination observed in human psychology. Generally, hallucinations in natural language generation tasks can be categorized into two primary types: *intrinsic hallucination* and *extrinsic hallucination* (Huang et al., 2021; Li et al., 2022b; Ji et al., 2023a). Specifically, *intrinsic hallucinations* pertain to the outputs of LLMs that conflict with the source content. Conversely, *extrinsic hallucinations* refer to the LLM generations that cannot be verified from the source content.

However, in the era of large language models, the *versatile* capabilities of these models have facilitated their widespread use across diverse fields, highlighting limitations in existing task-specific categorization paradigms. Considering that LLMs place a significant emphasis on user-centric interactions and prioritize alignment with user directives,

coupled with the fact that their hallucinations predominantly surface at factual levels, we introduce a more granular taxonomy building upon the foundational work by Ji et al. (2023a). This refined taxonomy seeks to encapsulate the distinct intricacies associated with LLM hallucinations. To provide a more *intuitive illustration* of our definition of LLM hallucination, we present examples for each type of hallucination in Table 1, accompanied by corresponding explanations. The details of our proposed categories are elaborated below:

Factuality Hallucination. The emergence of LLMs marks a significant shift from traditional task-specific toolkits to AI assistants that have a *heightened* focus on open-domain interactions. This shift is primarily attributed to their vast parametric factual knowledge. However, existing LLMs occasionally exhibit tendencies to produce outputs that are either inconsistent with real-world facts or potentially misleading, posing challenges to the trustworthiness of artificial intelligence. In this context, we categorize these factual errors as *factuality hallucinations*. Depending on whether the generated factual content can be verified against a reliable source, they can be further divided into two primary types:

- **Factual Inconsistency** refers to situations where the LLM’s output contains facts that can be grounded in real-world information, but present contradictions. This type of hallucination occurs most frequently and arises from diverse sources, encompassing the LLM’s capture, storage, and expression of factual knowledge. As shown in Table 1, when inquired about “*the first person to land on the Moon*”, the model erroneously generated “*Yuri Gagarin*”, which contradicts the real-world fact.
- **Factual Fabrication** refers to instances where the LLM’s output contains facts that are unverifiable against established real-world knowledge. As demonstrated in Table 1, while “*the origins of unicorns*” traditionally lack empirical grounding, the model fabricated a plausible historical origin for unicorns.

Faithfulness Hallucination. LLMs are inherently trained to align with user instructions. As the use of LLMs shifts towards more user-centric applications, ensuring their consistency with user-provided instructions and contextual information

Hallucination Type	Sub-Type	User Input	Model Output	Explanation
Factuality Hallucination	Factual Inconsistency	Tell me about the first person to land on the Moon.	Yuri Gagarin was the first person to land on the Moon.	The LLM's response is factual inconsistency as Neil Armstrong was the first person to land on the Moon , not Yuri Gagarin, who was the first human in space.
	Factual Fabrication	Tell me about the historical origins of unicorns.	Unicorns were documented to have roamed the plains of Atlantis around 10,000 BC, where they were considered sacred creatures and were often associated with royalty.	The LLM's response is a fabricated claim since there's no verified, real-world evidence supporting the existence of unicorns in Atlantis , especially in connection with royalty.
Faithfulness Hallucination	Instruction Inconsistency	Translate the following English question into Spanish: "What is the capital of France?"	The capital of France is Paris.	The user explicitly provided an instruction to translate the English question into Spanish. Instead of performing the translation as instructed, the LLM chose to answer the question.
	Context Inconsistency	Summarize the following paragraph about the Nile: The Nile is a major north-flowing river in northeastern Africa. It's traditionally considered the longest river in the world. Originating in the Great Lakes region of central Africa , it flows through several countries before emptying into the Mediterranean Sea.	The Nile originates from the mountain ranges of central Africa and flows into the Mediterranean.	The LLM's summary incorrectly states that the Nile originates from the "mountain ranges of central Africa," while the paragraph clearly mentions that the Nile originates in the Great Lakes region of central Africa.
	Logical Inconsistency	Solve the equation $2x + 3 = 11$ step by step.	Step 1: Subtract 3 from both sides to get: $2x = 8$. Step 2: Divide both sides by 2 to get: $x = 3$. So the result of the equation is $x=3$.	The first step correctly isolates the term with x to get $2x = 8$. However, the next step inaccurately divides 8 by 2 to yield a result of $x = 3$, which is inconsistent with the earlier reasoning.

Table 1: Examples of each category of LLM hallucinations. Content marked in **Red** represents the hallucinatory output, while content marked in **Blue** indicates user instruction or provided context that contradicts the LLM hallucination.

becomes increasingly vital. Furthermore, LLM’s faithfulness is also reflected in the logical consistency of its generated content. From this perspective, we categorize three subtypes of faithfulness hallucinations:

- **Instruction inconsistency** refers to the LLM’s outputs that deviate from a user’s directive. While some deviations might serve safety guidelines, the inconsistencies here signify unintentional misalignment with non-malicious user instructions. As described in Table 1, the user’s actual intention is translation. However, the LLM erroneously deviated from the user’s instruction and performed a question-answering task instead.
- **Context inconsistency** points to instances where the LLM’s output is unfaithful with the user’s provided contextual information. For example, as shown in Table 1, the user mentioned the Nile’s source being in the Great Lakes region of central Africa, yet the LLM’s response contradicted the context.
- **Logical inconsistency** underscores when LLM outputs exhibit internal logical contradictions, often observed in reasoning tasks. This manifests as inconsistency both among the reasoning steps themselves and between the steps and the final answer. For example, as shown in Table 1, while the reasoning step of dividing both sides of the equation by 2 is correct, the final answer of $x=4$ is inconsistent with the reasoning chain, leading to an incorrect result.

3 Hallucination Causes

Hallucinations have multifaceted origins, spanning the entire spectrum of LLMs’ capability acquisition process. In this section, we delve into the root causes of hallucinations in LLMs, primarily categorized into three key aspects: *Data* (§3.1), *Training* (§3.2), and *Inference* (§3.3).

3.1 Hallucination from Data

Pre-training data stands as the bedrock for LLMs, enabling them to gain general capabilities and factual knowledge (Zhou et al., 2023a). However, it can inadvertently become the source of LLM hallucinations. This mainly manifests in two aspects: potential risks stemming from flawed data

sources (§3.1.1), and the inferior utilization of factual knowledge captured in the data (§3.1.2).

3.1.1 Flawed Data Source

While scaling up pre-training data substantially enhances the competencies of LLMs (Kaplan et al., 2020; Hoffmann et al., 2022), challenges arise in maintaining consistent data quality, which can potentially introduce misinformation and biases (Bender et al., 2021; Weidinger et al., 2021). Moreover, the absence of specific domain knowledge and up-to-date facts in the data can lead the LLM to form knowledge boundaries, which pose limitations for LLMs in specific scenarios. Based on this, we primarily categorize the factors that could potentially lead to hallucinations into *misinformation and biases* and *knowledge boundary limitations*. For a more comprehensive understanding, illustrative examples of each type of data-induced hallucination are presented in Table 2.

Misinformation and Biases. Given the increasing demand for large-scale corpora, heuristic data collection methods are employed to efficiently gather vast volumes of data. While providing extensive data, they can inadvertently introduce erroneous information, increasing the risk of *imitative falsehoods*. Additionally, social biases can inadvertently be introduced into the LLMs’ learning process. These biases primarily include *duplication bias* and various *social biases*, potentially resulting in hallucinations.

- **Imitative Falsehoods.** The primary objective of LLM pre-training is to mimic the training distribution. When LLMs are trained on factual incorrect data, they may inadvertently *amplify* these inaccuracies, potentially leading to factually incorrect hallucinations, termed as "imitative falsehoods" (Lin et al., 2022). For example, as shown in Table 2, the statement '*Thomas Edison invented the light bulb*' is actually a misconception that has been widely misbelieved over time. LLMs trained on such factual incorrect data can lead to misleading outputs.

- **Duplication Bias.** Neural networks, especially large language models, *possess* an intrinsic tendency to memorize training data (Carlini et al., 2021). Studies (Carlini et al., 2022; Chowdhery et al., 2023) further show that this memorization tendency grows with

Type	Premise	Input	Model Output	Explanation
<i>Imitative Falsehood</i>	Within the LLM’s training data, a frequently referenced but incorrect fact appears multiple times: <i>Thomas Edison invented the light bulb.</i>	Who is credited with the invention of the light bulb?	Thomas Edison is credited with the invention of the light bulb.	While Edison improved the light bulb’s design, he was not its sole inventor. The model’s answer reflects a misconception prevalent in its training data, exemplifying an imitative falsehood.
<i>Duplication Bias</i>	Within the LLM’s pre-training data, there is an overwhelming repetition of the statement that <i>"The most common red fruits are red apples, watermelon, cherries, and strawberries."</i>	Please list some red fruits, excluding apples.	Red fruits are red apples, watermelon, cherries, and strawberries.	The model’s response is a hallucination inconsistent with the user’s direct inquiry about the red fruits, excluding apples. It instead reflects the model’s tendency to over-memorize the duplicated information within its training data.
<i>Social Biases</i>	In the model’s training data, certain names may frequently be associated with specific nationalities.	Provide a summary of the following news: Dr. Kim recently published a breakthrough paper on quantum computing. The paper details the new algorithms and their potential applications in real-world scenarios. It has been hailed as revolutionary by experts in the field.	Dr. Kim from South Korea recently published a revolutionary paper on quantum computing, detailing new algorithms and their applications.	The model erroneously added "South Korea" based on the name "Kim" revealing its bias in linking certain names to specific nationalities, which can cause hallucinations in the summary.

Table 2: Examples of Hallucinations from Misinformation and Biases. The table categorizes hallucinations arising from flawed data sources into imitative falsehoods, duplication bias, and social biases. Each category is accompanied by a premise outlining the data issue, user input, and the LLM’s hallucinatory output, and an explanation for the occurrence, aiding comprehension of these complex phenomena.

model size. However, the inherent memorization capability becomes problematic in the context of duplicated information present within pre-training data (Lee et al., 2022a; Kandpal et al., 2023; Paullada et al., 2021). Such duplication can shift LLMs from generalization to memorization (Hernandez et al., 2022), ultimately giving rise to a duplication bias where LLMs over-prioritize the recall of duplicated data and lead to hallucinations that deviate from the desired content. In Table 2, when the user requests to "list some red fruits, excluding apples," the presence of statements like "red apples, watermelon, cherries, and strawberries" frequently repeat in the training dataset leads the model to produce the over-memorized statement in its output.

- **Social Biases.** Certain biases are intrinsically tied to hallucinations, especially those related to gender (Paullada et al., 2021) and nationality (Narayanan Venkit et al., 2023; Ladhak et al., 2023). For instance, LLMs might associate the profession of nursing with females, even when gender isn’t explicitly mentioned in the user-provided context, exemplifying context inconsistency hallucinations as discussed in Section (§2.3). Such biases can be inadvertently acquired from internet-based texts, which are rife with diverse and biased viewpoints, and subsequently be propagated into the generated content (Ladhak et al., 2023). Besides such biases, discrepancies in data distribution also pose a potential cause for hallucinations. In the context of the natu-

ral language inference (NLI) task, McKenna et al. (2023) found that LLMs tend to falsely label by bias toward hypotheses affirmed in training data.

Knowledge Boundary. While the vast pre-training corpora empower LLMs with extensive factual knowledge, they inherently possess boundaries. This limitation primarily surfaces in two aspects: the absence of up-to-date factual knowledge and specialized domain knowledge. An example is presented in Table 3.

- **Domain Knowledge Deficiency.** LLMs have demonstrated remarkable performance across a wide range of downstream tasks in the generic domain. Nevertheless, given that these general-purpose LLMs are predominantly trained on extensive publicly available datasets (Penedo et al., 2023; Raffel et al., 2020; Gao et al., 2021), their expertise in specialized domains is inherently constrained by the absence of proprietary training data. As a result, when confronted with problems necessitating domain-specific knowledge, such as medical (Li et al., 2023g; Singhal et al., 2023) and legal (Yu et al., 2022; Katz et al., 2023) questions, these models may exhibit pronounced hallucinations, often manifesting as factual fabrication.
- **Outdated Factual Knowledge.** Beyond the shortfall in domain-specific knowledge, another intrinsic limitation concerning the knowledge boundaries within LLMs is their constrained capacity for up-to-date knowledge. The factual knowledge embedded within LLMs exhibits clear temporal boundaries and can become outdated over time (Onoe et al., 2022; Kasai et al., 2022; Li et al., 2023a). Once these models are trained, their internal knowledge is never updated. This poses a challenge given the dynamic and ever-evolving nature of our world. When confronted with queries that transcend their temporal scope, LLMs often resort to fabricating facts or providing answers that might have been correct in the past but are now outdated.

3.1.2 Inferior Data Utilization

Pre-training data embodies a wealth of real-world factual knowledge, enabling LLMs to capture and subsequently encode vast of factual knowledge

within their parameters (Petroni et al., 2019; Jiang et al., 2020; Roberts et al., 2020). However, despite this vast reservoir of knowledge, LLMs can still produce knowledge-induced hallucinations due to inferior utilization of parametric knowledge. In this context, we delve into two **pivotal** challenges: the spurious correlations in capturing factual knowledge and its struggles in knowledge recall. Examples for each type of hallucination related to inferior data utilization are presented in Table 4 for further illustration.

Knowledge Shortcut. While significant efforts have been undertaken in exploring their knowledge storage (Geva et al., 2021; Meng et al., 2022) and probing (Petroni et al., 2019; Zhong et al., 2021; Yu et al., 2023c), the exact mechanism by which LLMs capture the factual knowledge remains elusive. Recent studies (Li et al., 2022a; Kang and Choi, 2023; Kandpal et al., 2023) indicate that rather than genuinely understanding the intricacies of factual knowledge, LLMs often resort to shortcuts. They display a tendency to **overly depend on positional close** (Li et al., 2022a), co-occurrence statistics (Kang and Choi, 2023), and relevant document count (Kandpal et al., 2023) within the pre-training data, which can introduce a bias towards **spurious correlations**, potentially leading to hallucinations if the bias reflects factually incorrect information. For instance, as illustrated in Table 4, when queried about "*the capital of Canada*", the model erroneously responds with "Toronto". This mistake might arise due to a higher co-occurrence frequency of Canada and Toronto in its training data, leading the model to incorrectly capture the factual knowledge about Canada's capital.

Knowledge Recall Failures. Hallucinations can arise when LLMs struggle to effectively leverage their extensive knowledge. We explore two primary challenges in knowledge recall: the inadequacy in recalling long-tail knowledge and difficulties in complex scenarios that require multi-hop reasoning and logical deduction.

- **Long-tail Knowledge** Within the vast knowledge landscape that LLMs draw upon, a notable challenge emerges in the form of long-tail knowledge utilization (Kandpal et al., 2023; Mallen et al., 2023). This long-tail knowledge, characterized by its relative rarity in pre-training data, poses inherent challenges for LLMs, which primarily rely on co-occurrence patterns to memorize factual

Type	Input	Model Output	Explanation
Domain Knowledge Deficiency	What causes phenylketonuria?	Phenylketonuria is caused by a mutation in the hemoglobin gene, which results in an unusual interaction with hemoglobin, affecting its ability to transport oxygen in the bloodstream.	Phenylketonuria (PKU) is actually caused by mutations in the gene that helps make an enzyme called phenylalanine hydroxylase. Due to the lack of specialized medical knowledge in LLM’s training data, it may sometimes provide incorrect information on medical topics.
Outdated Knowledge	Which city hosted the most recent Winter Olympics?	The most recent city to host the Winter Olympics was Pyeongchang, South Korea, in 2018.	The most recent city to host the Winter Olympics was Beijing, in 2022. This is due to the fact that LLM stores outdated knowledge, and the answer to this question exhibits a time-shift phenomenon.

Table 3: Example of Knowledge Boundary.

knowledge. Consequently, when confronted with queries pertaining to such long-tail knowledge, LLMs are at a heightened risk of hallucination, attempting to generate factually inaccurate responses. For instance, as shown in Table 4, when prompted to generate a biography for a long-tail entity previously encountered in Wikipedia training data, the LLM erroneously attributes the profession, mistakenly describing a politician as an educator.

- **Complex Scenario** Beyond the challenges with long-tail knowledge, effective utilization of knowledge is inextricably linked with reasoning capabilities. For instance, in multi-hop question-answering scenarios, even if the LLM possesses the necessary knowledge, it may struggle to produce accurate results if multiple associations exist between questions, due to its limitations in reasoning (Zheng et al., 2023). Furthermore, Berglund et al. (2023) unveiled a specific reasoning failure in LLMs termed the *Reversal Curse*. Specifically, while the model can correctly answer when the question is formulated as "A is B", it exhibits a failed logical deduction when asked the converse "B is A". This discrepancy in reasoning extends beyond simple deductions. In retrieval-augmented settings, Liu et al. (2023e) highlighted a related challenge.

Despite having documents containing the correct answers within the model’s context window, the model still struggles to generate precise responses due to its inadequacy in utilizing the provided evidence effectively. As illustrated in Table 4, although LLMs recognize Mount Everest as the world’s highest peak, they fail to determine which would become the highest mountain if Everest’s elevation were reduced by 500 meters, a task that requires complex reasoning ability.

3.1.3 Summary

Data-related hallucinations in LLMs are primarily rooted in flawed data sources and inferior data utilization. Misinformation and inherent biases within data sources not only propagate imitative falsehoods but also introduce biased outputs, leading to various forms of hallucinations. Knowledge boundaries in LLMs become evident when handling domain-specific queries or encountering rapidly updating factual knowledge. Regarding data utilization, LLMs tend to capture spurious correlations and demonstrate difficulties in recalling knowledge, especially long-tail information, and in complex reasoning scenarios, further exacerbating hallucinations. These challenges underscore the critical need for enhancing data quality and the models’ capabilities to learn and recall factual knowledge more effectively.

Type	Sub-Type	User Input	Model Output	Explanation
Knowledge Recall Failures	Co-occurrence Bias	What is the capital of Canada?	Toronto is the capital of Canada.	The model leans heavily on the frequent co-occurrence of the terms <i>Toronto</i> and <i>Canada</i> in its training data, without truly capturing the factual knowledge about the capital of Canada
	Long-tail Knowledge	Please generate a biography for George James Rankin.	George James Rankin is a dedicated educator known for his contributions to the field of education and his passion for fostering learning.	George James Rankin is actually a politician , but the LLM may have difficulty effectively utilizing knowledge about this long-tail entity despite being trained on comprehensive Wikipedia data during pre-training.
	Complex Reasoning	If Mount Everest were to descend by 500 meters, which mountain would become the world's highest peak?	If Mount Everest were to descend by 500 meters, it would still remain the world's highest peak.	The height of Mount Everest is 8844.43 meters, while K2's height is 8611 meters. If Mount Everest were to descend by 500 meters, K2 would become the world's highest peak. Facing complex multi-step reasoning questions like this, LLM may struggle to recall all the relevant knowledge associated with it.

Table 4: Examples of Inferior Data Utilization, showcasing the pitfalls of knowledge shortcuts and failures in knowledge recall. This includes instances where LLMs capture factual knowledge relying on co-occurrence statistics, as well as situations where it cannot recall relevant information from its parametric knowledge.

3.2 Hallucination from Training

The training process of LLMs mainly encompasses two primary stages: 1) the pre-training stage, where LLMs learn general-purpose representations and capture world knowledge, and 2) the alignment stage, where LLMs are adapted to better align with user instructions and preferences. While this process equips LLMs with remarkable capabilities, any shortfalls in these stages can inadvertently lead to hallucinations.

3.2.1 Hallucination from Pre-training

Pre-training serves as the foundational stage for LLMs, typically employing a transformer-based architecture to conduct causal language modeling on vast corpora. However, issues related to hallucination may arise from the inherent architectural design and the particular training strategies employed. In this section, we delve into the challenges posed

by the architecture flaw and impacts of exposure bias.

Architecture Flaw. LLMs typically adopt a transformer-based architecture following the **paradigm established** by GPT (Radford et al., 2018, 2019; Brown et al., 2020), where they acquire representations through a causal language modeling objective, a framework exemplified by models such as OPT (Zhang et al., 2022), Falcon (Penedo et al., 2023), and Llama-2 (Touvron et al., 2023). Despite its success, it is not without its pitfalls, particularly concerning *Inadequate Unidirectional Representation* and *Attention Glitches*.

- **Inadequate Unidirectional Representation.**

Following the causal language modeling paradigm, LLMs predict the subsequent token based solely on preceding tokens in a left-to-right manner. This **unidirectional** modeling, while facilitating efficient training, also

has its limitations. It exclusively **utilizes context from a single direction**, which hinders its ability to capture intricate contextual dependencies, potentially increasing risks for the emergence of hallucination (Li et al., 2023h).

- **Attention Glitches.** Transformer-based architecture, equipped with the self-attention module, has shown remarkable capabilities in capturing long-range dependencies. However, Recent research (Liu et al., 2023a) has shown that they can **occasionally** exhibit unpredictable reasoning errors in the **context of algorithmic reasoning**, spanning both long-range and short-range dependencies, regardless of model scale. A potential cause is the limitations of soft attention (Hahn, 2020; Chiang and Cholak, 2022), where attention becomes diluted across positions as sequence length increases.

Exposure Bias. Beyond the architecture flaw, training strategies also play a crucial role. Notably, the phenomenon of exposure bias (Bengio et al., 2015; Ranzato et al., 2016) stands out, resulting from the disparity between training and inference in the auto-regressive generative model. During training, these models **typically employ a teacher-forced maximum likelihood estimation** (MLE) training strategy where ground truth tokens are provided as input. However, during inference, the model relies on its own generated tokens for **subsequent predictions**. Such inconsistency can result in hallucinations (Wang and Sennrich, 2020), especially when an erroneous token generated by the model cascades errors throughout the subsequent sequence, akin to a snowball effect (Zhang et al., 2023c).

3.2.2 Hallucination from Alignment

Alignment, which typically involves two main processes, supervised fine-tuning and reinforcement learning from human feedback, serves as a crucial step toward unlocking the capabilities of LLMs and aligning them with human preferences. While alignment notably enhances the quality of LLM responses, it also introduces the risk of hallucinations. In this section, we will categorize the alignment shortfalls related to hallucinations into two parts: *Capability Misalignment* and *Belief Misalignment*.

Capability Misalignment. Considering that LLMs have inherent capability boundaries established during pre-training, SFT utilizes high-quality instructions along with their corresponding

responses to empower LLMs to follow user instructions, **unlocking their acquired abilities in this process**. However, as the capabilities of LLMs expand, a significant challenge emerges: the potential misalignment between the LLMs' intrinsic capabilities and those depicted in the annotation data. When the demands from alignment data exceed these pre-defined capability boundaries, LLMs are trained to produce content beyond their own knowledge boundaries, amplifying the risk of hallucinations (Schulman, 2023).

Belief Misalignment. Several studies have demonstrated that LLM's activations encapsulate an internal belief related to the truthfulness of its generated statements (Burns et al., 2022; Azaria and Mitchell, 2023). Nevertheless, misalignment can occasionally arise between these internal beliefs and the generated outputs. Even when LLMs are refined with human feedback (Ouyang et al., 2022), **they can sometimes produce outputs that diverge from their internal beliefs**. Such behaviors, termed as **sycophancy** (Cotra, 2021), **underscores the model's inclination to appease human evaluators**, often at the cost of truthfulness. Recent studies indicate that models trained via RLHF exhibit pronounced behaviors of **pandering to user opinions**. Such sycophantic behaviors are not restricted to ambiguous questions without definitive answers (Perez et al., 2023), like political stances, but can also arise when the model chooses a clearly incorrect answer, despite being aware of its inaccuracy (Wei et al., 2023). Delving into this phenomenon, (Sharma et al., 2023) suggests that the root of sycophancy may lie in the training process of RLHF models. By further exploring the role of human preferences in this behavior, the research indicates that the tendency for sycophancy is likely driven by both humans and preference models showing a bias towards sycophantic responses over truthful ones.

3.2.3 Summary

In training LLMs, both the foundational pre-training and the subsequent alignment present unique challenges that can induce hallucinations. During the pre-training stages, architecture flaws, notably inadequate unidirectional representation, and attention glitches, coupled with the well-known exposure bias, contribute to hallucinations. Meanwhile, in the alignment phase, issues of capability misalignment and belief misalignment arise. The former risks pushing LLMs beyond their knowl-

edge boundaries, while the latter reveals a disparity between the LLM’s beliefs and its outputs. These challenges underscore the importance of training LLMs to ensure their truthfulness. From foundational model designs and training strategies to align with human expectations, it remains a multifaceted endeavor.

3.3 Hallucination from Inference

Decoding plays an important role in manifesting the capabilities of LLMs after pre-training and alignment. However, certain shortcomings within decoding strategies can lead to LLM hallucinations. In this section, we delve into potential causes rooted in the decoding process, emphasizing two critical factors: the inherent randomness of decoding strategies (§3.3.1) and imperfect decoding representation (§3.3.2).

3.3.1 Inherent Sampling Randomness

LLMs have demonstrated a remarkable aptitude for generating highly creative and diverse content, a proficiency that is critically dependent on the pivotal role of *randomness* in their decoding strategies. Stochastic sampling (Fan et al., 2018; Holtzman et al., 2020) is currently the prevailing decoding strategy employed by these LLMs. The rationale for incorporating randomness into decoding strategies stems from the realization that high likelihood sequences often result in surprisingly low-quality text, which is called *likelihood trap* (Stahlberg and Byrne, 2019; Holtzman et al., 2020; Meister et al., 2020; Zhang et al., 2021). The diversity introduced by the randomness in decoding strategies comes at a cost, as it is positively correlated with an increased risk of hallucinations (Dziri et al., 2021a; Chuang et al., 2023). An elevation in the sampling temperature results in a more uniform token probability distribution, increasing the likelihood of sampling tokens with lower frequencies from the tail of the distribution. Consequently, this heightened tendency to sample infrequently occurring tokens exacerbates the risk of hallucinations (Aksitov et al., 2023).

3.3.2 Imperfect Decoding Representation

During the decoding phase, LLMs use their top-layer representation to predict the next token. However, the top-layer representation has its limitations, primarily manifested in two aspects: *Insufficient Context Attention* and *Softmax Bottleneck*.

Insufficient Context Attention. Prior studies, particularly in domains like machine translation (Miao et al., 2021) and summarization (Chen et al., 2022b), have highlighted the issue of *over-confidence* in generative models employing encoder-decoder architectures. Such over-confidence stems from an excessive focus on the partially generated content, often prioritizing fluency at the expense of faithfully adhering to the source context. While large language models, primarily adopting the causal language model architecture, have gained widespread usage, the *over-confidence* phenomenon continues to persist. During the generation process, the prediction of the next word is conditioned on both the language model context and the partially generated text. However, as demonstrated in prior studies (Voita et al., 2019; Beltagy et al., 2020; Liu et al., 2023e), language models often exhibit a *localized focus within their attention mechanisms*, giving priority to nearby words and resulting in a notable deficit in context attention (Shi et al., 2023b). Furthermore, this concern is further amplified in LLMs that exhibit a proclivity for generating lengthy and comprehensive responses. In such cases, there is even a heightened susceptibility to the risk of *instruction forgetting* (Chen et al., 2023f; Liu et al., 2023i). This insufficient attention can directly contribute to faithfulness hallucinations, wherein the model outputs content that deviates from the original context.

Softmax Bottleneck. The majority of language models utilize a softmax layer that operates on the final layer’s representation within the language model, in conjunction with a word embedding, to compute the ultimate probability associated with word prediction. Nevertheless, the efficacy of Softmax-based language models is impeded by a *recognized limitation known as the Softmax bottleneck* (Yang et al., 2018a), wherein the employment of softmax in tandem with distributed word embeddings is constrained the expressivity of the output probability distributions given the context which prevents LMs from outputting the desired distribution. Additionally, Chang and McCallum (2022) discovered that when the desired distribution within the output word embedding space exhibits multiple modes, language models face challenges in accurately prioritizing words from all the modes as the top next words, which also introduces the risk of hallucination.

3.3.3 Summary

During the decoding phase, challenges arise from both the inherent decoding strategy and the representation utilized for predicting. The former, emphasizing the randomness rooted in its decoding algorithm, can be a source of hallucinations as the randomness increases. While on the representation side, issues such as the over-reliance on nearby content and the softmax bottleneck can limit the model’s capability to express diverse output probabilities, leading to the risk of inaccurate token predictions. These complexities underscore the necessity of maintaining factuality and faithfulness throughout the decoding process.

4 Hallucination Detection and Benchmarks

Hallucinations, as exhibited by LLMs, have garnered substantial attention due to their implications on model reliability and real-world deployment. As models become increasingly adept at generating human-like text, distinguishing between accurate and hallucinated content becomes a pivotal concern. Two primary facets encompass the broad spectrum of hallucination mitigation: detection mechanisms and evaluation benchmarks. This section serves as a deep dive into the state-of-the-art techniques for detecting hallucinations (§4.1) and the benchmarks (§4.2) that evaluate their prowess.

4.1 Hallucination Detection

Detecting hallucinations in LLMs is imperative for assuring the reliability and trustworthiness of the generated content. Traditional metrics, predominantly hinged on word overlap, fall short in differentiating the nuanced discrepancies between plausible and hallucination content. Such a challenge highlights the necessity for more sophisticated detection methods tailored to LLM hallucinations. Given the diverse nature of these hallucinations, detection approaches vary accordingly. Consequently, in this section, we provide a comprehensive overview of primary hallucination detection strategies, tailored to factuality and faithfulness hallucinations.

4.1.1 Factuality Hallucination Detection

Research by (Chen and Shu, 2023) underscored the challenge humans face in identifying ChatGPT-generated misinformation, leading to increasing studies aiming to design detection methods target-

ing factuality hallucination. In this context, we propose an overview of established methods, typically categorized into Retrieve External Facts and Uncertainty Estimation.

Retrieve External Facts. To effectively pinpoint factual inaccuracies in LLM outputs, one **intuitive** strategy involves comparing the model-generated content against reliable knowledge sources, as shown in Fig. 3. This methodology closely aligns with the workflow of fact-checking tasks, as delineated by (Guo et al., 2022). Nevertheless, traditional fact-checking methodologies (Augenstein et al., 2019; Hanselowski et al., 2019; Atanasova et al., 2020) often incorporate simplified assumptions for practicality, leading to discrepancies when applied to complex real-world scenarios. Recognizing these constraints, Chen et al. (2023c) place greater emphasis on real-world scenarios, **wherein evidence is procured from time-constrained, uncured web sources**. They have pioneered a fully automated pipeline that integrates multiple components: claim decomposition, raw document retrieval, fine-grained retrieval, claim-focused summarization, and veracity classification. Galitsky (2023) further addresses situations where potential conflict retrieval evidence by finding the least defeated authoritative source and avoiding the most defeated. Furthermore, Min et al. (2023) introduced FACTSCORE, a fine-grained factual metric specifically for long-form text generation. It decomposes the generation content into atomic facts and subsequently computes the percentage supported by reliable knowledge sources. Recently, Huo et al. (2023) enhanced the standard approach of retrieving supporting evidence for hallucination detection through query expansion. By combining the original question with the LLM-generated answer during the retrieval process, they addressed topic drift concerns, ensuring that the retrieved passages align with both the question and the LLM’s response. In a broader perspective, Chern et al. (2023) proposed a unified framework that enables LLMs to detect factual errors by leveraging a suite of external tools for evidence collection.

Uncertainty Estimation. While many approaches to hallucination detection rely on external knowledge sources for fact-checking, **several methods have been devised to address this issue in zero-resource settings, thus eliminating the need for retrieval**. The foundational premise behind these strategies is that the origin of LLM hallucinations

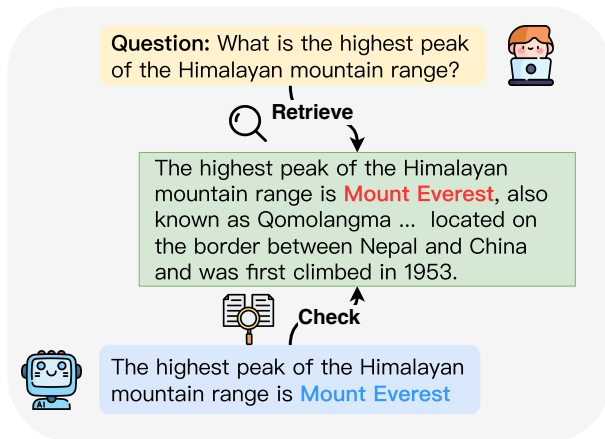


Figure 3: An example of detecting factuality hallucination by retrieving external facts.

is inherently **tied to the model’s uncertainty** . Therefore, by estimating the uncertainty of the factual content generated by the model, it becomes feasible to detect hallucinations. The methodologies in uncertainty estimation can broadly be categorized into two approaches: based on *internal states* and *LLM behavior*, as shown in Fig. 4. The former operates under the assumption that one can access the model’s internal states, while the latter generalizes to more constrained environments, leveraging solely the model’s observable behaviors to infer its underlying uncertainty.

- **LLM Internal States.** The internal states of LLMs can serve as informative indicators of their uncertainty, often manifested through metrics like token probability or entropy. Varshney et al. (2023) determine the model’s uncertainty towards key concepts quantified by considering the minimal token probability within those concepts. The underlying rationale is that a low probability serves as a strong indicator of the model’s uncertainty, with less influence from higher probability tokens present in the concept. Similarly, Luo et al. (2023a) employed a self-evaluation-based approach for uncertainty estimation by grounding in the rationale that a language model’s ability to adeptly reconstruct an original concept from its generated explanation is indicative of its proficiency with that concept. By initially prompting the model to generate an explanation for a given concept and then employing constrained decoding to have the model recreate the original concept based on its generated explanation, the probability

score from the response sequence can serve as a familiarity score for the concept. Furthermore, Yao et al. (2023a) interpreted hallucination through the lens of adversarial attacks. Utilizing gradient-based token replacement, they devised prompts to induce hallucinations. Notably, they observed that the first token generated from a raw prompt typically exhibits low entropy, compared to those from adversarial attacks. Based on this observation, they proposed setting an entropy threshold to define such hallucination attacks.

- **LLM Behavior.** However, when systems are only accessible via API calls (OpenAI, 2022; Google, 2023; Microsoft, 2023), access to the output’s token-level probability distribution might be unavailable. Given this constraint, several studies have shifted their focus to probing a model’s uncertainty, either through natural language prompts (Xiong et al., 2023; Kadavath et al., 2022) or by examining its behavioral manifestations. For instance, by sampling multiple responses from an LLM for the same prompt, Manakul et al. (2023) **detect hallucinations via evaluating the consistency among the factual statements** . However, these methods predominantly rely on direct queries that explicitly solicit information or verification from the model. Agrawal et al. (2023), inspired by investigative interviews, advocate for the use of indirect queries. Unlike direct ones, these indirect counterparts often pose **open-ended questions to elicit specific information** . By employing these indirect queries, consistency across multiple model generations can be better evaluated. Beyond assessing uncertainty from the self-consistency of a single LLM’s multiple generations, one can embrace a multi-agent perspective by incorporating additional LLMs. Drawing inspiration from legal cross-examination practices, Cohen et al. (2023) introduced the LMvLM approach. **This strategy leverages an ‘examiner’ LM to question an ‘examinee’ LM, aiming to unveil inconsistencies of claims during multi-turn interaction.**

4.1.2 Faithfulness Hallucination Detection

Ensuring the faithfulness of LLMs to provide context or user directives is pivotal for their practical utility in a myriad of applications, from summariza-

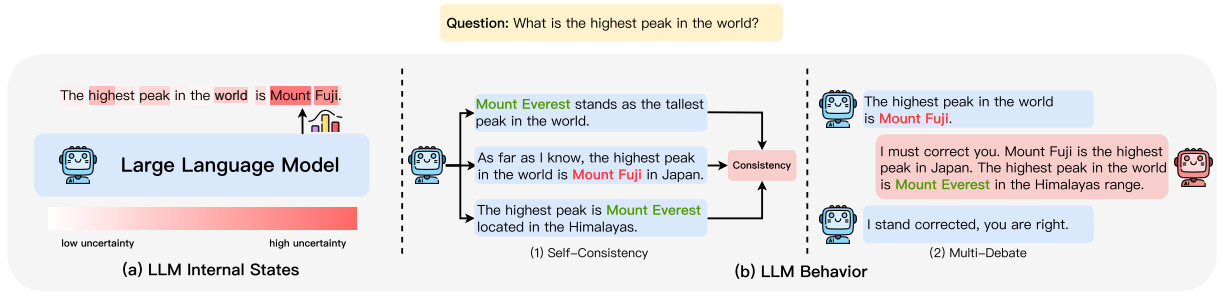


Figure 4: Taxonomy of Uncertainty Estimation Methods in Factual Hallucination Detection, featuring **a) LLM Internal States** and **b) LLM Behavior**, with LLM Behavior encompassing two main categories: Self-Consistency and Multi-Debate.

tion to interactive dialogue systems. Faithfulness hallucination detection primarily focuses on ensuring the alignment of the generated content with the given context, sidestepping the potential pitfalls of extraneous or contradictory output. In this subsection, we explore the methods to detect unfaithfulness in LLM generations and provide an overview of in Fig. 5.

Fact-based Metrics. In the realm of assessing faithfulness, one of the most intuitive methods involves measuring the overlap of pivotal facts between the generated content and the source content. Given the diverse manifestations of facts, metrics can be categorized based on entities, relation triples, and knowledge.

- **N-gram based.** When treating the source content as the reference, traditional n-gram overlap-based evaluation metrics, such as ROUGE (Lin, 2004) and PARENT-T (Wang et al., 2020b), can also be applied to assess faithfulness. However, due to the natural diversity of language expression and their reliance on surface-level matching, these metrics show poor correlation with humans (Maynez et al., 2020).
- **Entity-based.** Metrics based on entity overlap are prevalently applied in summarization tasks, as any omission or inaccurate generation of these key entities could lead to an unfaithful summary. Nan et al. (2021) introduced a metric to quantify the extent of entity hallucination, which calculates the precision of named-entities in the summary against the source entities.
- **Relation-based.** Noting that even if entities match, the relations between them might be

erroneous. Thus, Goodrich et al. (2019) focus on the overlap of relation tuples and introduce a metric that computes the overlap of relation tuples extracted using trained end-to-end fact extraction models.

- **Knowledge-based.** Similarly, for knowledge-grounded dialogue tasks, facts often correspond to the knowledge presented in the dialogue. Shuster et al. (2021) introduced the Knowledge F1 metric to assess how well the model’s generation aligns with the supplied knowledge.

Classifier-based Metrics. Beyond computing fact overlap, another straightforward approach to assessing the faithfulness of the model involves utilizing classifiers trained on comprising both task-specific hallucinated and faithful content, as well as data from related tasks or synthetically generated data. It can be broadly categorized into the following types:

- **Entailment-based.** A prevailing concept in using Natural Language Inference (NLI) for assessing the faithfulness of generated text is anchored on the idea that genuinely faithful content should inherently be entailed by its source content. In line with this, numerous studies (Falke et al., 2019; Maynez et al., 2020) have trained classifiers on NLI datasets to identify factual inaccuracies, especially in the context of abstract summarization. However, Mishra et al. (2021) highlighted that the mismatch in input granularity between conventional NLI datasets and inconsistency detection datasets limits their applicability for effectively detecting inconsistencies. Building on this, more advanced studies have proposed

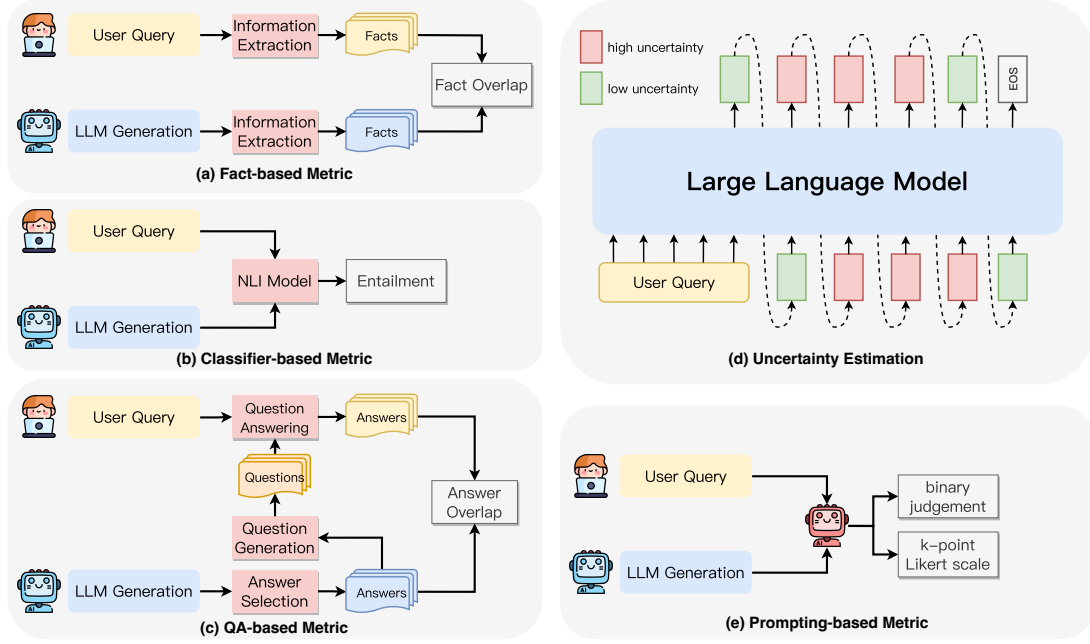


Figure 5: The illustration of detection methods for faithfulness hallucinations: **a) Fact-based Metrics**, which assesses faithfulness by measuring the overlap of facts between the generated content and the source content; **b) Classifier-based Metrics**, utilizing trained classifiers to distinguish the level of entailment between the generated content and the source content; **c) QA-based Metrics**, employing question-answering systems to validate the consistency of information between the source content and the generated content; **d) Uncertainty Estimation**, which assesses faithfulness by measuring the model’s confidence in its generated outputs; **e) Prompting-based Metrics**, wherein LLMs are induced to serve as evaluators, assessing the faithfulness of generated content through specific prompting strategies.

methods such as fine-tuning on adversarial datasets (Barrantes et al., 2020), decomposing the entailment decisions at the dependency arc level (Goyal and Durrett, 2020), and segmenting documents into sentence units then aggregating scores between sentence pairs (Laban et al., 2022). These collective efforts underscore the potential to enhance the accuracy of hallucination detection.

- **Weekly Supervised.** While using data from related tasks to fine-tune the classifier has shown promise in evaluating faithfulness, it’s essential to recognize the inherent gap between related tasks and the downstream task. The scarcity of annotated data further constrains their applicability. In response to this challenge, Kryscinski et al. (2020) analyzed errors made by cutting-edge summarization models and introduced a method using rule-based transformations to create weakly-supervised data for fine-tuning the classifier. Concurrently, Zhou et al. (2021) devised an approach to automatically generate token-level hallucination data and perform token-

level hallucination detection. Building upon the work of (Kryscinski et al., 2020), Dziri et al. (2021b) utilized perturbation methods to generate adversarial synthetic data aiming to enhance hallucination detection in knowledge-grounded dialogue tasks while Santhanam et al. (2021) focuses on factual consistency for the conversation domain.

Question-Answering based Metrics. In contrast to classifier-based metrics, QA-based metrics have recently garnered attention for their enhanced ability to capture information overlap between the model’s generation and its source. These metrics operate by initially selecting target answers from the information units within the LLM’s output, and then questions are generated by the question-generation module. The questions are subsequently used to generate source answers based on the user context. Finally, the faithfulness of the LLM’s responses is calculated by comparing the matching scores between the source and target answers. Notable implementations include (Durmus et al., 2020; Wang et al., 2020a; Scialom et al., 2021; Honovich et al., 2021). Although these method-

ologies share a common thematic approach, they exhibit variability in aspects like answer selection, question generation, and answer overlap, leading to diverse performance outcomes. Building on this foundational work, Fabbri et al. (2022) conducted an in-depth evaluation of the components within QA-based metrics, yielding further enhancements in faithfulness evaluation.

Uncertainty Estimation. Drawing from the insights in Section (§4.1.1), hallucinations in conditional text generation are closely tied to high model uncertainty. Uncertainty estimation has been widely explored in **Bayesian deep learning** (Blundell et al., 2015; Gal and Ghahramani, 2016; Lakshminarayanan et al., 2017). From a Bayesian perspective, the total uncertainty of a prediction is characterized by the predictive entropy of the output distribution. Moreover, some works (Malinin and Gales, 2021) have sought to quantify model uncertainty using log probability. Based on these principles, we categorize the existing approaches for hallucination detection via uncertainty estimation into the following types:

- **Entropy based.** Xiao and Wang (2021) observed a positive correlation between hallucination likelihood in data-to-text generation and predictive uncertainty, which is estimated by deep ensembles (Lakshminarayanan et al., 2017). Furthermore, Guerreiro et al. (2023a) leveraged the variance in hypotheses yielded by Monte Carlo Dropout (Gal and Ghahramani, 2016) as an uncertainty measure within Neural Machine Translation (NMT). More recently, van der Poel et al. (2022) employed conditional entropy (Xu et al., 2020) to assess model uncertainty in abstractive summarization.
- **log-probability-based.** Guerreiro et al. (2023a) use length-normalised sequence log-probability to measure model confidence.
- **Model based.** Miao et al. (2023) concentrates on error detection in complex reasoning by employing SelfCheck, a step-by-step checker that evaluates each reasoning step within LLMs. The system aggregates confidence scores through a streamlined process of target extraction, information collection, step regeneration, and result comparison, thereby enhancing question-answering accuracy.

Prompting-based Metrics. Recently, the remarkable instruction-following ability of LLMs has underscored their potential for automatic evaluation (Chiang and Lee, 2023; Liu et al., 2023g; Wang et al., 2023d). Exploiting this capability, researchers have ventured into novel paradigms for assessing the faithfulness of model-generated content (Luo et al., 2023b; Laban et al., 2023; Adlakha et al., 2023; Gao et al., 2023b; Jain et al., 2023). By providing LLMs with concrete evaluation guidelines and feeding them both the model-generated and source content, they can effectively assess faithfulness. The final evaluation output can either be a binary judgment on faithfulness (Luo et al., 2023b) or a k-point Likert scale indicating the degree of faithfulness (Gao et al., 2023b). For prompt selection, evaluation prompt can either be direct prompting, chain-of-thought prompting (Adlakha et al., 2023), using in-context-learning (Jain et al., 2023) or allowing the model to generate evaluation results accompanying with explanations (Laban et al., 2023).

4.2 Benchmarks

In this section, we present a comprehensive overview of existing hallucination benchmarks, which can be categorized into two primary domains: Hallucination Evaluation Benchmarks (§4.2.1), which assess the extent of hallucinations generated by existing cutting-edge LLMs, and Hallucination Detection Benchmarks (§4.2.2), designed specifically to evaluate the performance of existing hallucination detection methods. Collectively, these benchmarks establish a unified framework, enabling a nuanced and thorough exploration of hallucinatory patterns in LLMs.

4.2.1 Hallucination Evaluation Benchmarks

Hallucination evaluation benchmarks are devised to assess LLMs’ proclivity to produce hallucinations, with a particular emphasis on identifying factual inaccuracies and measuring deviations from original contexts. Presently, the primary focus of these benchmarks is on evaluating the factuality of LLM-generated content. While most are structured in a question-answering format, their primary focus remains on LLM factuality. Their unique characteristics stem from the selected knowledge domain, language, and response format they employ. We present an overview of the most representative benchmarks in detail below and concurrently provide an evaluation of common LLMs’ perfor-

Benchmark	Datasets	Data Size	Language	Attribute			Task			
				Factuality	Faithfulness	Manual	Task Type	Input	Label	Metric
TruthfulQA (Lin et al., 2022)	-	817	English	✓	✗	✓	Generative QA Multi-Choice QA	Question	Answer	LLM-Judge & Human
REALTIMEQA (Kasai et al., 2022)	-	Dynamic	English	✓	✗	✓	Multi-Choice QA Generative QA	Question	Answer	Acc EM & F1
SelfCheckGPT-Wikibio (Miao et al., 2023)	-	1,908	English	✗	✓	✗	Detection	Paragraph & Concept	Passage	AUROC
HaluEval (Li et al., 2023c)	Task-specific	30,000	English	✗	✓	✗	Detection	Query	Response	Acc
	General	5,000	English	✗	✓	✗	Detection	Task Input	Response	Acc
Med-HALT (Umapathi et al., 2023)	-	4,916	Multilingual	✓	✗	✗	Multi-Choice QA	Question	Choice	Pointwise Score & Acc
FACTOR (Muhlgay et al., 2023)	Wiki-FACTOR	2,994	English	✓	✗	✗	Multi-Choice QA	Question	Answer	likelihood
	News-FACTOR	1,036	English	✓	✗	✗	Multi-Choice QA	Question	Answer	likelihood
BAMBOO (Dong et al., 2023)	SenHallu	200	English	✗	✓	✗	Detection	Paper	Summary	P & R & F1
	AbsHallu	200	English	✗	✓	✗	Detection	Paper	Summary	P & R & F1
ChineseFactEval (Wang et al., 2023a)	-	125	Chinese	✓	✗	✓	Generative QA	Question	-	Score
HaluQA (Cheng et al., 2023)	Misleading	175	Chinese	✓	✗	✓	Generative QA	Question	Answer	LLM-Judge
	Misleading-hard	69	Chinese	✓	✗	✓	Generative QA	Question	Answer	LLM-Judge
	Knowledge	206	Chinese	✓	✗	✓	Generative QA	Question	Answer	LLM-Judge
FreshQA (Vu et al., 2023)	Never-changing	150	English	✓	✗	✓	Generative QA	Question	Answer	Human
	Slow-changing	150	English	✓	✗	✓	Generative QA	Question	Answer	Human
	Fast-changing	150	English	✓	✗	✓	Generative QA	Question	Answer	Human
	False-premise	150	English	✓	✗	✓	Generative QA	Question	Answer	Human
FELM (Chen et al., 2023d)	-	3,948	English	✓	✓	✗	Detection	Question	Response	Balanced Acc & F1
PHD (Yang et al., 2023)	PHD-LOW	100	English	✗	✓	✗	Detection	Entity	Response	P & R & F1
	PHD-Medium	100	English	✗	✓	✗	Detection	Entity	Response	P & R & F1
	PHD-High	100	English	✗	✓	✗	Detection	Entity	Response	P & R & F1
ScreenEval (Lattimer et al., 2023)	-	52	English	✗	✓	✗	Detection	Document	Summary	AUROC
RealHall (Friel and Sanyal, 2023)	COVID-QA	N/A	English	✗	✓	✗	Detection	Question	Answer	AUROC
	DROP	N/A	English	✗	✓	✗	Detection	Question	Answer	AUROC
	Open Assistant	N/A	English	✗	✓	✗	Detection	Question	Answer	AUROC
	TriviaQA	N/A	English	✗	✓	✗	Detection	Question	Answer	AUROC
LSum (Feng et al., 2023a)	-	6,166	English	✗	✓	✗	Detection	Document	Summary	Balanced Acc
SAC ³ (Zhang et al., 2023a)	HotpotQA	250	English	✗	✓	✗	Detection	Question	Answer	AUROC
	NQ-Open	250	English	✗	✓	✗	Detection	Question	Answer	AUROC

Table 5: An overview of existing hallucination benchmarks. For Attribute, **Factuality** and **Faithfulness** represent whether the benchmark is used to evaluate LLM’s factuality or to detect faithfulness hallucination, and **Manual** represents whether the inputs in the data are handwritten.

mances on these benchmarks in the (§A).

TruthfulQA (Lin et al., 2022). Comprising 817 questions that span 38 diverse categories, such as health, law, finance, and politics, TruthfulQA is a benchmark specifically designed to assess the truthfulness of language models. Crafted using an adversarial methodology, it aims to elicit "imitative falsehoods"—misleading responses that models might generate due to their frequent presence in training data. The benchmark is divided into two parts, one of which contains manually curated questions that were further refined by filtering out those correctly answered by GPT-3, resulting in 437 filtered questions. The other part includes 380 unfiltered non-adversarial questions. For evaluation, TruthfulQA offers two types of question-answering tasks: generation and multiple-choice, with human evaluation employed to gauge the models’ truthfulness

and informativeness. Moreover, the benchmark introduces an automatic metric named GPT-judge, which is fine-tuned on a 6.7B GPT-3 model.

REALTIMEQA (Kasai et al., 2022). Considering that world knowledge is constantly evolving, it becomes crucial to validate the LLM’s factuality concerning the current world. This benchmark offers real-time open-domain multiple-choice questions derived from newly-published news articles, spanning diverse topics such as politics, business, sports, and entertainment. Additionally, the benchmark provides a platform for real-time evaluations, either through a multiple-choice format assessed by accuracy or a generation setting evaluated using exact matching and token-based F1 metrics.

Med-HALT (Umapathi et al., 2023). Given the critical consequences of hallucinations in the medical domain on patient care, the benchmark em-

phasizes challenges specific to LLMs in the medical domain. Med-HALT, incorporating multiple-choice questions from various countries, is tailored to assess LLMs’ reasoning and memorization in the medical context. The reasoning task, with 18,866 samples, tests LLMs’ ability to distinguish incorrect or irrelevant options and fake questions by using multiple-choice medical questions. Meanwhile, the memory task, comprising 4,916 samples, evaluates LLMs’ ability to recall and generate accurate factual information by either generating links from a PubMed abstract/title or producing titles from given links and PMIDs. For evaluation, the performance of LLMs is measured either by their accuracy on test questions or by a Pointwise Score that considers both the positive scores for correct answers and a negative penalty for incorrect ones.

FACTOR (Muhlgay et al., 2023). To quantitatively assess LM factuality, Muhlgay et al. (2023) introduced a method for automatically creating benchmarks by perturbing factual statements from a designated corpus, resulting in two benchmarks: Wiki-FACTOR and News-FACTOR. Specifically, for a given prefix text, the original completion from the corpus serves as the factually correct answer. InstructGPT is then guided with prompts that contain specific error types to generate non-factual completions. These generated responses are subsequently filtered for fluency and self-consistency, serving as the foundation for multi-choice tasks. For evaluation, an LM’s factuality is gauged by whether the likelihood of the model producing the factually correct completion exceeds that of generating other non-factual completions.

ChineseFactEval (Wang et al., 2023a). By gathering questions from diverse domains such as general knowledge, scientific research, medicine, law, finance, mathematics, and modern Chinese history, ChineseFactEval employed 125 questions to evaluate the factual capabilities of six contemporary Chinese LLMs, alongside GPT-4. For evaluation, questions are categorized based on the accuracy achieved by various LLMs, with different scores assigned to questions of varying difficulty. The responses from all LLMs are primarily annotated by humans, supplemented by FacTool (Chern et al., 2023). The final scores of the LLMs are then used to assess their factuality.

HalluQA (Cheng et al., 2023). Drawing from the construction approach of TruthfulQA (Lin et al., 2022), HalluQA is crafted to specifically assess

hallucinations in Chinese large language models, focusing on imitative falsehoods and factual errors. The benchmark comprises 450 handcrafted adversarial questions across 30 domains and is categorized into two parts. The misleading section captures questions that successfully deceive GLM-130B, while the knowledge section retains questions that both ChatGPT and Puyu consistently answer incorrectly. For evaluation, LLMs generate responses to these questions, which are then compared with correct answers using GPT-4 to determine whether an answer contains hallucinations.

FreshQA (Vu et al., 2023). Recognizing that hallucinations can partially arise from outdated knowledge within LLMs, the benchmark is introduced to evaluate the factuality of existing LLMs. Comprising 600 hand-crafted questions whose answers may change over time or whose premises are factually incorrect, this benchmark primarily evaluates the LLMs’ aptitude for fast-changing knowledge and their ability to identify questions with false premises. For evaluation, the benchmark provides a two-mode evaluation procedure: RELAXED, which solely evaluates the correctness of the primary answer, and STRICT, which further assesses the accuracy of every fact within the answer. In both modes, the factuality of the LLM is reflected by the accuracy of its responses, as determined through human annotations.

4.2.2 Hallucination Detection Benchmarks

For hallucination detection benchmarks, most prior studies have primarily concentrated on task-specific hallucinations, such as abstractive summarization (Kryscinski et al., 2020; Wang et al., 2020a; Maynez et al., 2020; Fabbri et al., 2021; Goyal and Durrett, 2021; Pagnoni et al., 2021; Tang et al., 2022), data-to-text (Tian et al., 2019; Parikh et al., 2020), and machine translation (Zhou et al., 2021). However, the content generated in these studies often originates from models with lesser capabilities, such as BART (Lewis et al., 2020a) and PEGASUS (Zhang et al., 2020). As a result, they may not accurately reflect the effectiveness of hallucination detection strategies. Therefore, such studies fall outside the scope of our current discussion.

SelfCheckGPT-Wikibio (Miao et al., 2023). Miao et al. (2023) introduced a sentence-level hallucination detection dataset by generating synthetic Wikipedia articles using GPT-3, based on concepts from the WikiBio dataset. The factuality of these passages was then manually annotated at the sen-

tence level, yielding a total of 1908 sentences for 238 articles.

HaluEval (Li et al., 2023c). To assess the capability of LLMs in recognizing hallucination, HaluEval was constructed using a combination of automated generation and human annotation, yielding 5,000 general user queries paired with ChatGPT responses and 30,000 task-specific samples. The automated generation employed a "sampling-then-filtering" approach. Drawing upon task-specific datasets from question answering, knowledge-grounded dialogue, and text summarization, the benchmark initially uses ChatGPT to sample multifaceted hallucinated answers based on task-related hallucination patterns and then select the most plausible hallucinated samples by ChatGPT. For human annotation, Alpaca-sourced queries were processed by ChatGPT to sample multiple responses, which were then manually assessed for the presence of hallucinated content.

BAMBOO (Dong et al., 2023). Expanding upon the methodologies introduced by Li et al. (2023c), this benchmark introduces two new datasets, SenHallu and AbsHallu, aimed at detecting hallucination in the context of long texts. These datasets are constructed by inducing ChatGPT to generate hallucinations given academic papers, resulting in 200 samples, respectively.

FELM (Chen et al., 2023d). Unlike previous studies that predominantly focused on specific tasks such as summarization (Fabbri et al., 2021; Tang et al., 2022) or particular domains such as world knowledge (Miao et al., 2023), this benchmark assesses factuality across five domains: world knowledge, science and technology, mathematics, writing and recommendation, and reasoning. While earlier research intentionally induced LLMs to hallucinate based on specific patterns (Li et al., 2023c), this benchmark employs ChatGPT to generate responses in a zero-shot setting, yielding a total of 817 samples (comprising 3948 segments). Each segment is annotated for factuality, error reasons, error type, and external references. Serving as a testbed for factuality detectors, the benchmark employs the F1 score and balanced classification accuracy to evaluate factual errors at both the segment and response levels.

PHD (Yang et al., 2023). Rather than focusing on sentence-level hallucination detection, the benchmark emphasizes passage-level detection. The construction of the benchmark begins with the

extraction of entities from the Wikipedia dump, followed by generating passages using ChatGPT. Recognizing that factuality errors often arise when LLMs lack sufficient knowledge, the benchmark selects entities based on the number of related items returned by Google Search. This categorization results in three distinct groups: PHD-Low, PHD-Medium, and PHD-High. From each category, 100 entities are sampled and then human-annotated at the passage level as *factual*, *non-factual*, or *un-verifiable*. For the evaluation process, the benchmark employs Precision, Recall, and F1 measures to assess the effectiveness of methods in detecting non-factual passages.

ScreenEval (Lattimer et al., 2023). Building upon existing research predominantly focused on short documents, the ScreenEval benchmark extends the scope to factual inconsistencies in long-form dialogues. Based on the SummScreen dataset (Chen et al., 2022a), which comprises TV scripts and human-crafted summaries, this benchmark introduces factual inconsistency annotations for summaries generated by Longformer and GPT-4 at sentence level, resulting in a dataset of 52 documents and 624 summary sentences. As for evaluation, hallucination detection methods are evaluated on this benchmark using the AUROC score.

RealHall (Friel and Sanyal, 2023). The construction of this benchmark follows the principles that tasks within a hallucination detection benchmark ought to present a substantive challenge to LLMs and bear relevance to real-world applications while ensuring a breadth of diversity. In alignment with this, the benchmark concentrates on question-answering tasks, categorizing them into *Closed* and *Open* groups based on the availability of a reference text in the prompt. Each question within the benchmark is initially approached using ChatGPT for generating responses, which are subsequently assigned boolean ground-truth labels through a combined approach involving human annotation, GPT-4 evaluation, and automated rule-based assessment. The efficacy of hallucination detection methodologies applied to this benchmark is quantified using the AUROC score.

LSum (Feng et al., 2023a). The benchmark centers on factual consistency detection within the summarization tasks undertaken by LLMs. Built on XSum (Narayan et al., 2018), the benchmark involves generating summaries using various LLMs, from the GPTfamily, GLM-family, and LLaMA-

family and annotating the factual consistency on the sentence level by employing ChatGPT and GPT-4, resulting in a total of 6,166 annotated summaries.

SAC³ (Zhang et al., 2023a). The benchmark comprises two datasets: HotpotQA-halu and NQ-open-halu. These datasets were constructed by sampling 250 examples from the training set of HotpotQA (Yang et al., 2018b) and NQ-open (Kwiatkowski et al., 2019), respectively. Hallucinated answers were then generated using gpt-3.5-turbo. Then, the answers were manually annotated, which involved comparing them with the ground truth and relevant knowledge sources.

5 Hallucination Mitigating

In this section, we present a comprehensive review of contemporary methods aimed at mitigating hallucinations in LLMs. Drawing from insights discussed in *Hallucination Causes*(§3), we systematically categorize these methods based on the underlying causes of hallucinations. Specifically, we focus on approaches addressing *Data-related Hallucinations*(§5.1), *Training-related Hallucinations*(§5.2) and *Inference-related Hallucinations*(§5.3), each offering tailored solutions to tackle specific challenges inherent to their respective cause.

5.1 Mitigating Data-related Hallucinations

Data-related hallucinations generally emerge as a byproduct of biases, misinformation, and knowledge gaps, which are fundamentally rooted in the training data. In this context, we explore various strategies for mitigating such hallucinations, aiming to minimize the occurrence of misinformation and biases, while also providing knowledge augmentation and enhancing the effective utilization of knowledge by LLMs.

5.1.1 Mitigating Misinformation and Biases

To reduce the presence of misinformation and biases, the most intuitive approach is to collect high-quality factual data to prevent the introduction of misinformation and conduct data cleansing to debias.

Factuality Data Enhancement. Maintaining the factual correctness of the training data is crucial in mitigating issues like imitative falsehood (Lin et al., 2022). The most direct approach is the manual curation of the pre-training dataset. As early as the advent of GPT-2, Radford et al. (2019)

underscored the significance of exclusively scraping web pages that had undergone rigorous curation and filtration by human experts. However, as pre-training datasets continue to scale, manual curation becomes a challenge. Given that academic or specialized domain data is typically factually accurate, gathering high-quality data emerges as a primary strategy. Notable examples include *the Pile* (Gao et al., 2021) and “textbook-like” data sources (Gunasekar et al., 2023; Li et al., 2023f). Additionally, up-sampling factual data during the pre-training phase has been proven effective in enhancing the factual correctness of LLMs (Touvron et al., 2023), thus alleviating hallucination.

Debias. Biases within pre-training data can typically be classified into two main categories: *duplication bias* and *societal biases*, each requiring distinct debiasing approaches.

- **Duplication Bias.** Deduplication serves as a crucial procedure in the pre-training phase. Existing practices typically fall into two categories: *exact duplicates* and *near-duplicates*. For exact duplicates, the most straightforward method involves *exact substring* matching to identify identical strings. However, given the vastness of pre-training data, this process can be computationally intensive. In addition, a more efficient method utilizes the construction of a suffix array (Manber and Myers, 1993), enabling effective computation of numerous substring queries in linear time. Regarding near-duplicates, the identification often involves approximate full-text matching, typically utilizing hash-based techniques to identify document pairs with significant n-gram overlap. Furthermore, MinHash (Broder, 1997) stands out as a prevalent algorithm for large-scale deduplication tasks (Gyawali et al., 2020). Additionally, SemDeDup (Abbas et al., 2023) makes use of embeddings from pre-trained models to identify semantic duplicates, which refers to data pairs with semantic similarities but not identical.
- **Societal Biases.** Given the vastness and unfathomable nature of pre-training data, directly addressing the root cause of societal biases is a formidable challenge (Ferrara, 2023). Consequently, current mainstream solutions lean heavily on curated training corpora. By carefully selecting diverse, balanced, and rep-

representative training data, we can mitigate biases (Paullada et al., 2021; Narayanan Venkit et al., 2023; Ladhak et al., 2023) that may trigger hallucinations. Additionally, toolkits (Viswanath and Zhang, 2023) have been introduced to enable users to debiasing both existing and custom models.

5.1.2 Mitigating Knowledge Boundary

Constrained by the coverage and temporal boundaries of training data, inevitably form knowledge boundaries, introducing notable challenges. To tackle these challenges, two popular approaches have gained significant attention. One is *Knowledge editing* (Sinitsin et al., 2020; Yao et al., 2023c), which aims at directly editing model parameters to bridge the knowledge gap. The other leveraging non-parametric knowledge sources through *Retrieval-Augmented Generation (RAG)* (Lewis et al., 2020b; Guu et al., 2020; Shuster et al., 2021).

Knowledge Editing. Knowledge editing De Cao et al. (2021); Sinitsin et al. (2020) has garnered rising attention from researchers, which aims to rectify model behavior by incorporating additional knowledge. Current knowledge editing techniques can fix factual errors and refresh outdated information to mitigate the knowledge gap, which can be categorized into two classes: changing the model’s behavior by modifying the model parameters or using an external model plug-in with the original model frozen (Yao et al., 2023c).

- **Modifying Model Parameters.** These techniques directly inject knowledge into the original model, leading to a substantial alteration in the model’s output, which can be further split into *locate-then-edit methods* and *meta-learning methods*.

Locate-then-edit methods (Dai et al., 2022a; Meng et al., 2022) consist of two stages, which first locate the “buggy” part of the model parameters and then apply an update to them to alter the model’s behavior. For example, ROME (Meng et al., 2022) locates the edits-related layer by destroying and subsequently restoring the activations and then updates the parameters of FFN in a directed manner to edit knowledge. MEMIT (Meng et al., 2023) employs the same knowledge locating methods as ROME, enabling the concurrent updating of multiple layers to facilitate the si-

multaneous integration of thousands of editing knowledge. However, Yao et al. (2023c) finds that these methods lack non-trivial generalization capabilities and varying performance and applicability to different model architectures. The best-performing methods ROME (Meng et al., 2022) and MEMIT (Meng et al., 2023) empirically only work well on decoder-only LLMs.

Meta-learning methods (De Cao et al., 2021; Mitchell et al., 2022a) train an external hyper-network to predict the weight update of the original model. Nevertheless, meta-learning methods often require additional training and memory cost, necessitating specialized design to reduce the size of hyper-networks in the age of LLMs (*e.g.* low-rank decomposition (Mitchell et al., 2022a)). While these methods can fine-grainedly adjust the behavior of the model, modifications to the parameters could have a potentially harmful impact on the inherent knowledge of the model.

- **Preserving Model Parameters.** Instead of directly modifying model parameters, a line of studies apply an additional model plug-in into the original model to achieve the desired change in model behavior. SERAC (Mitchell et al., 2022b) employs a scope classifier to route the input associated with new knowledge stored in an external edit memory toward the counterfactual model, which can aid the base model in handling the updated information.

In comparison to the whole model, there are various techniques that involve incorporating additional parameter layers (*e.g.* adapter layers (Hartvigsen et al., 2022)) as plug-ins into the original model. T-Patcher (Huang et al., 2023d) and NKB (Dai et al., 2022b) both add the patches into FFN layers which are acknowledged as the repository storing knowledge (Geva et al., 2021) to rectify the factual mistakes. CALINET (Dong et al., 2022) proposes an assessment for identifying erroneous knowledge in PLMs and similarly adjusts the output of FFNs by introducing FFN-like memory slots, which is beneficial to alleviate the knowledge gap. These methods require additional steps to train the parameter module, carefully designing training functions

and structures to promote the plug-in to play a role in updated knowledge while keeping unedited facts handled by the original module.

Knowledge editing methods can effectively introduce knowledge to mitigate the model’s knowledge gap to some extent. Nevertheless, there is room for enhancement in the impact of knowledge editing. (Zhong et al., 2023b) proposes MQUAKE to evaluate the generalization of injected knowledge and finds that the post-edited model can successfully recall the edited facts but fails in complex multi-hop questions. There are also some studies (Wu et al., 2023; Wang et al., 2023e) indicating that existing editing methods exhibit limited cross-language generalization capabilities. Furthermore, Pinter and Elhadad (2023) suggests that knowledge editing techniques introduce potential risk to users when attempting to mitigate hallucinations of LLMs and advises utilizing methods incorporating explicit knowledge (e.g. retrieval-augmented methods).

Retrieval Augmentation. An intuitive way to mitigate the knowledge gap is Retrieval-Augmented Generation (RAG)(Lewis et al., 2020b; Guu et al., 2020; Shuster et al., 2021), grounding the LLMs during generation by conditioning on relevant documents retrieved from an external knowledge source. Typically, RAG follows a retrieve-then-read pipeline, where relevant contextual documents are firstly retrieved by a *retriever* (Karpukhin et al., 2020) from external sources, and then the desired output is generated by a *generator* conditioning on both input text and retrieved documents. We categorize the methods to mitigate hallucination using retrieval augmentation into three types, including *one-time retrieval*, *iterative retrieval*, and *post-hoc retrieval*.

- **One-time Retrieval.** One-time retrieval aims to directly prepend the external knowledge obtained from a single retrieval to the LLMs’ prompt. Ram et al. (2023) introduces In-context RALM, which entails a straightforward yet effective strategy of prepending chosen documents to the input text of LLMs. Demonstrated empirical results indicate that the employment of In-context RALM consistently translates into enhanced performance across varying LLM sizes and a diverse array of corpora. Notably, the incorporation of a

ranking mechanism has been shown to further amplify performance gains.

Beyond conventional knowledge repositories such as Wikipedia, ongoing research endeavors have explored alternative avenues, specifically the utilization of knowledge graphs (KGs). These KGs serve as a pivotal tool for prompting LLMs, facilitating their interaction with the most recent knowledge, and eliciting robust reasoning pathways (Wen et al., 2023; Qi et al., 2023; Baek et al., 2023). Varshney et al. (2023) introduce the Parametric Knowledge Guiding (PKG) framework, enhancing LLMs with domain-specific knowledge. PKG employs a trainable background knowledge module, aligning it with task knowledge and generating relevant contextual information. The effectiveness of PKG highlights the potential for enhancing LLMs’ faithfulness by incorporating retrieved background knowledge.

- **Iterative Retrieval.** However, when confronted with intricate challenges like multi-step reasoning (Yang et al., 2018c) and long-form question answering (Fan et al., 2019; Stelmakh et al., 2022), traditional one-time retrieval may fall short.

Addressing these demanding information needs, recent studies have proposed **iterative retrieval**, which allows for continuously gathering knowledge throughout the generation process. A burgeoning line of research (Khot et al., 2022; Yao et al., 2022; Press et al., 2022; He et al., 2023; Trivedi et al., 2023) endeavors to tackle such intricate tasks by **decomposing them into more manageable sub-tasks**. Recognizing the substantial advancements chain-of-thought prompting has brought to LLMs in multi-step reasoning Wei et al. (2022), numerous studies (Yao et al., 2022; Trivedi et al., 2023; He et al., 2023) try to incorporate external knowledge at each reasoning step and further guide retrieval process based on ongoing reasoning, **reducing factual errors in reasoning chains**. Building upon chain-of-thought prompting, Press et al. (2022) introduced *self-ask*. Diverging from the conventional continuous, undelineated chain-of-thought prompting, *self-ask* delineates the question it intends to address at each step, subsequently incorporating a search action based on the follow-up ques-

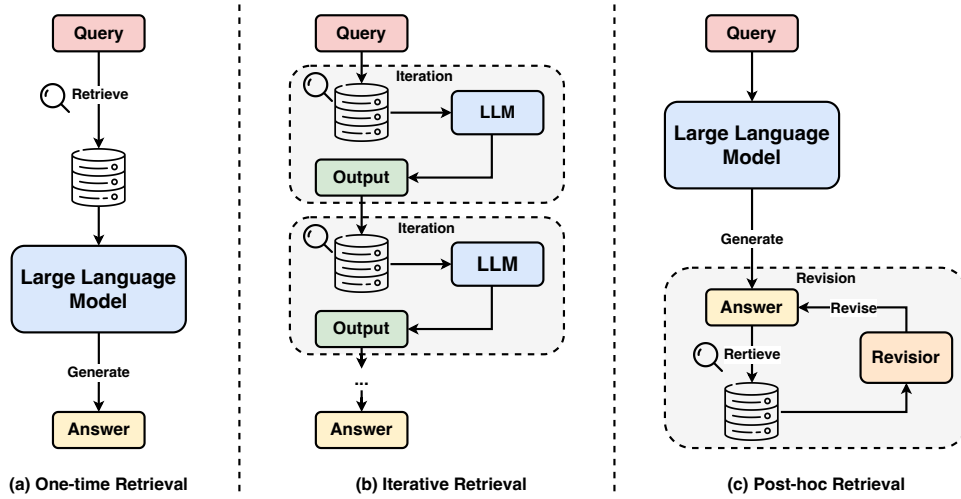


Figure 6: The illustration of three distinct approaches for Retrieval-Augmented Generation: **a) One-time Retrieval**, where relevant information is retrieved once before text generation; **b) Iterative Retrieval**, involving multiple retrieval iterations during text generation for dynamic information integration; and **c) Post-hoc Retrieval**, where the retrieval process happens after an answer is generated, aiming to refine and fact-check the generated content.

tion. Instead of solely depending on chain-of-thought prompting for retrieval guidance, both [Feng et al. \(2023b\)](#) and [Shao et al. \(2023\)](#) employ an iterative retrieval-generation collaborative framework, where a model’s response serves as an insightful context to procure more relevant knowledge, subsequently refining the response in the succeeding iteration.

Beyond multi-step reasoning tasks, [Jiang et al. \(2023\)](#) shift their emphasis to long-form generation. They proposed an active retrieval augmented generation framework, which iteratively treats the upcoming prediction as a query to retrieve relevant documents. If the prediction contains tokens of low confidence, the sentence undergoes regeneration. In addition to using iterative retrieval to improve intermediate generations, [Zhang et al. \(2023e\)](#) present MixAlign, which iteratively refines user questions using model-based guidance and seeking clarifications from users, ultimately enhancing the alignment between questions and knowledge.

- **Post-hoc Retrieval.** Beyond the traditional *retrieve-then-read* paradigm, a line of work has delved into post-hoc retrieval, refining LLM outputs through subsequent retrieval-based revisions.

To enhance the trustworthiness and attribution of LLMs, [Gao et al. \(2023a\)](#) adopt the *research-then-revise* workflow, which initially research relevant evidence and subsequently

revise the initial generation based on detected discrepancies with the evidence. Similarly, [Zhao et al. \(2023a\)](#) introduce the *verify-and-edit* framework to enhance the factual accuracy of reasoning chains by incorporating external knowledge. For reasoning chains that show lower-than-average consistency, the framework generates verifying questions and then refines the rationales based on retrieved knowledge, ensuring a more factual response. [Yu et al. \(2023d\)](#) enhanced the post-hoc retrieval method through diverse answer generation. Instead of generating just a single answer, they sample various potential answers, allowing for a more comprehensive retrieval feedback. Additionally, by employing an ensembling technique that considers the likelihood of the answer before and after retrieval, they further mitigate the risk of misleading retrieval feedback.

5.1.3 Mitigating Knowledge Shortcut

Knowledge shortcuts manifest when LLMs lean on spurious correlations, such as the co-occurrence statistics of the pre-training corpora, to capture factual knowledge. [Kang and Choi \(2023\)](#) suggested fine-tuning on a debiased dataset constructed by excluding biased samples. Although this leads to a notable decline in the recall of frequent facts as more samples are excluded, this method struggles to generalize when rare facts are unseen during finetuning.

5.1.4 Mitigating Knowledge Recall Failures

A prevalent source of hallucinations in LLMs is their inability to accurately retrieve and apply relevant information embedded in their parametric knowledge. This challenge is particularly acute in complex reasoning scenarios where the integrity of information is critical. By enhancing knowledge recall, we can better anchor the model’s outputs to verifiable knowledge, thereby providing a more robust defense against generating hallucination content. Typically, the most direct approach to recall knowledge is enabling LLMs to reason via Chain-of-Thought prompting. [Zhong et al. \(2023b\)](#) suggest that simply applying CoT can increase knowledge recall, which substantially boosts performance in editing facts under multi-hop settings. Instead of incorporating reasoning steps, [Zheng et al. \(2023\)](#) posit that directly supplementing questions with relevant information can enhance the model’s ability to recall crucial knowledge. [Wang et al. \(2023g\)](#) advance this by employing conceptualization, which distills original commonsense knowledge into high-level abstract knowledge, boosting knowledge recall.

5.2 Mitigating Training-related Hallucination

Training-related hallucinations typically arise from the intrinsic limitations of the architecture and training strategies adopted by LLMs. In this context, we discuss various optimization methods ranging from training stages (§5.2.1) and alignment stages (§5.2.2), aiming to mitigate hallucinations within the training process.

5.2.1 Mitigating Pretraining-related Hallucination

To address pretraining-related hallucination, the majority of research emphasizes the exploration of novel model architectures and the improvement of pre-training objectives.

Mitigating Flawed Model Architecture. One significant avenue of research in mitigating pretraining-related hallucination centers on the limitations inherent in model architectures, especially *unidirectional representation* and *attention glitches*. In light of this, numerous studies have delved into designing novel model architectures specifically tailored to address these flaws.

- **Mitigating Unidirectional Representation.** Addressing the limitations inherent in unidirectional representation, [Li et al. \(2023h\)](#)

introduced BATGPT that employs a bidirectional autoregressive approach. This design allows the model to predict the next token based on all previously seen tokens, considering both past and future contexts, thus capturing dependencies in both directions. Building on this idea, [Liu et al. \(2023e\)](#) highlighted the potential of encoder-decoder models to make better use of their context windows, suggesting a promising direction for future LLMs architecture design.

- **Mitigating Attention Glitches.** Recognizing the limitations of soft attention within self-attention-based architecture, [Liu et al. \(2023a\)](#) proposed attention-sharpening regularizers. This plug-and-play approach sparsifies self-attention architectures using differentiable loss terms ([Zhang et al., 2018](#)) to promote sparsity, leading to a significant reduction in reasoning hallucinations.

Mitigating Suboptimal Pre-training Objective.

In the pre-training phase of LLMs, the choice of objective plays a pivotal role in determining the model’s performance. However, conventional objectives can lead to fragmented representations and inconsistencies in model outputs. Recent advancements have sought to address these challenges by refining pre-training strategies, ensuring richer context comprehension, and circumventing biases. This section sheds light on these pioneering approaches, encompassing both novel training objectives and efforts to counteract exposure bias.

- **Training Objective.** Addressing the inherent limitations in training LLMs, where unstructured factual knowledge at a document level often gets chunked due to GPU memory constraints and computational efficiency, leading to fragmented information and incorrect entity associations, [Lee et al. \(2022b\)](#) introduced a factuality-enhanced training method. By appending a TOPICPREFIX to each sentence in factual documents, the approach transforms them into standalone facts, significantly reducing factual errors and enhancing the model’s comprehension of factual associations. Similarly, considering that randomly concatenating shorter documents during pre-training might introduce inconsistencies in model outputs,

Shi et al. (2023c) propose In-Context Pretraining, an innovative approach in which LLMs are trained on sequences of related documents. By altering the document order, this method aims to maximize similarity within the context windows. It explicitly encourages LLMs to reason across document boundaries, potentially bolstering the logical consistency between generations.

- **Exposure Bias.** Exposure bias-induced hallucinations are intricately tied to error accumulation, as noted by (Arora et al., 2022). While several approaches have proposed Chen et al. (2020); Welleck et al. (2020); Bertsch et al. (2023) to mitigate exposure bias, few studies are directly linked to the hallucinations. To bridge this gap, Wang et al. (2023b) introduce the incorporation of intermediate sequences as supervision signals within the permutation multi-task learning framework to mitigate spurious correlations in domain-shift scenarios in NMT. Additionally, by employing the Minimum Bayes Risk decoding (Shen et al., 2016), it can further reduce hallucinations related to exposure bias.

5.2.2 Mitigating Misalignment Hallucination

Hallucinations induced during alignment often stem from capability misalignment and belief misalignment. However, defining the knowledge boundary of LLMs proves challenging, making it difficult to bridge the gap between LLMs’ inherent capabilities and the knowledge presented in human-annotated data. While limited research addresses capability misalignment, the focus mainly shifts toward belief misalignment.

Hallucinations stemming from belief misalignment often manifest as sycophancy, a tendency of LLMs to seek human approval in undesirable ways. This sycophantic behavior can be attributed to the fact that human preference judgments often favor sycophantic responses over more truthful ones (Sharma et al., 2023), paving the way for reward hacking (Saunders et al., 2022). To address this, a straightforward strategy is to improve human preference judgments and, by extension, the preference model. Recent research (Bowman et al., 2022; Saunders et al., 2022) has investigated the use of LLMs to assist human labelers in identifying overlooked flaws. Additionally, Sharma et al. (2023) discovered that aggregating multiple human prefer-

ences enhances feedback quality, thereby reducing sycophancy.

Besides, modifications to LLMs’ internal activations have also shown the potential to alter model behavior. This can be achieved through methods like fine-tuning (Wei et al., 2023) or activation steering during inference (Dathathri et al., 2020; Subramani et al., 2022; Gu et al., 2022b,c; Hernandez et al., 2023). Specifically, Wei et al. (2023) proposed a synthetic-data intervention, fine-tuning language models using synthetic data where the claim’s ground truth is independent of a user’s opinion, aiming to reduce sycophantic tendencies.

Another avenue of research (Rimsky, 2023b,a) has been to mitigate sycophancy through activation steering. This approach involves using pairs of sycophantic/non-sycophantic prompts to generate the sycophancy steering vector, derived from averaging the differences in intermediate activations. During inference, subtracting this vector can produce less sycophantic LLM outputs.

5.3 Mitigating Inference-related Hallucination

Decoding strategies in Large Language Models play a pivotal role in determining the factuality and faithfulness of the generated content. However, As analyzed in Section §3.3, imperfect decoding often results in outputs that might lack factuality or stray from the original context. In this subsection, we explore two advanced strategies aimed at refining the decoding strategy to enhance both the factuality and faithfulness of the LLMs’ outputs.

5.3.1 Factuality Enhanced Decoding

Factuality Enhanced Decoding focuses on ensuring the factuality of the information produced by LLMs. By emphasizing the accuracy of facts, this strategy aims to generate outputs that adhere strictly to real-world information and resist producing misleading or false statements.

On Standalone Decoding. Considering the randomness in the sampling process can introduce non-factual content into open-ended text generation, Lee et al. (2022b) introduced the factual-nucleus sampling algorithm that dynamically adjusts the “nucleus” p throughout sentence generation. By dynamically adjusting the nucleus probability based on decay factors and lower boundaries and resetting the nucleus probability at the beginning of every new sentence, the decoding strategy strikes a balance between generating factual content and

preserving output diversity.

Moreover, some studies (Burns et al., 2022; Moschella et al., 2022) posit that the activation space of LLMs contains interpretable structures related to factuality. Building on this idea, Li et al. (2023d) introduce Inference-Time Intervention (ITI). This method first identifies a direction in the activation space associated with factually correct statements and then adjusts activations along the truth-correlated direction during inference. By repeatedly applying such intervention, LLMs can be steered towards producing more factual responses.

Similarly, Chuang et al. (2023) delve into enhancing the factuality of LLM’s decoding process from a perspective of factual knowledge storage. They exploit the hierarchical encoding of factual knowledge within transformer LLMs, noting that lower-level information is captured in earlier layers and semantic information in the later ones. Drawing inspiration from Li et al. (2022c), they introduce DoLa, a strategy that dynamically selects and contrasts logits from different layers to refine decoding factuality. By placing emphasis on knowledge from higher layers and downplaying that from the lower layers, DoLa showcases its potential to make LLMs more factual, thus reducing hallucinations.

Post-editing Decoding. Unlike methods that directly modify the probability distribution to prevent hallucinations during the initial decoding, post-editing decoding seeks to harness the self-correction capabilities of LLMs (Pan et al., 2023) to refine the originally generated content without relying on an external knowledge base. Dhuliawala et al. (2023) introduced the Chain-of-Verification (COVE), which operates under the assumption that, when appropriately prompted, LLMs can self-correct their mistakes and provide more accurate facts. Starting with an initial draft, it first formulates verification questions and then systematically answers those questions in order to finally produce an improved revised response. Similarly, Ji et al. (2023b) focus on the medical domain and introduce an iterative self-reflection process. This process leverages the inherent ability of LLMs to first generate factual knowledge and then refine the response until it aligns consistently with the provided background knowledge.

5.3.2 Faithfulness Enhanced Decoding

On the other hand, Faithfulness Enhanced Decoding prioritizes alignment with the user instructions or provided context and also emphasizes enhancing the consistency within the generated content. Thus, in this section, we summarize existing work into two categories, including *Context Consistency* and *Logical Consistency*.

Context Consistency. Decoding strategies that prioritize context consistency are designed to enhance the faithfulness of LLMs to both user instructions and the provided context. Before the era of LLMs, prior studies extensively explored improvements in context consistency, predominantly in the fields of abstractive summarization and data-to-text. Tian et al. (2019) proposed confident decoding that incorporates a confidence score during the decoding process to measure the model’s attention level to the source. By emphasizing the source more when the confidence score is high, they mitigate hallucinations stemming from a lack of context attention. van der Poel et al. (2022) shifts the decoding objective to pointwise mutual information. This approach encourages the model to prioritize tokens relevant to the source document, especially when model uncertainty rises, aiming to prevent hallucinations. In contrast to previous strategies that emphasized enhanced attention to the source for bolstering context consistency, Wan et al. (2023) delved into whether better exploration of the search space could improve faithfulness. By using automatic faithfulness metrics to rank candidates generated by beam search and incorporating lookahead heuristics that assign a faithfulness score to the future generation, they achieved significant improvements in faithfulness compared to existing decoding strategies.

However, in the era of LLMs, the issue of hallucinations due to insufficient attention to context remains. Shi et al. (2023b) propose context-aware decoding (CAD), which modifies the output distribution by reducing reliance on prior knowledge, thereby promoting the model’s focus on the contextual information, similar to that presented by (van der Poel et al., 2022). However, due to the inherent trade-off between diversity and attribution (Gu et al., 2022a), overemphasizing contextual information can reduce diversity. In response, Chang et al. (2023a) introduced an innovative sampling algorithm to bolster attribution while preserving diversity. This method involves two parallel de-

codings, one considering the source and the other not, and adjusts the temperature dynamically using the KL divergence between their token distributions to reflect source attribution. [Lei et al. \(2023\)](#) explored a more generic post-edit framework to mitigate faithfulness hallucinations during inference. This approach first detects hallucinations at both the sentence and entity levels and then utilizes this detection feedback to refine the generated response. Furthermore, [Choi et al. \(2023\)](#) introduced knowledge-constrained decoding (KCD), which employs a token-level hallucination detection to identify hallucinations and guides the generation process by reweighing the token distribution with a better estimate of the future knowledge-groundedness. Besides, considering that the softmax bottleneck constrains the expression of diversity and faithful representations. A line of work explores methods to overcome the bottleneck, either by a mixture of Softmax, which uses multiple hidden states to compute softmax multiple times and merge the resulting distributions ([Yang et al., 2019](#)) or using pointer networks to enable LLMs to copy the context words ([Chang et al., 2023b](#)), further reducing hallucinations.

Logical Consistency. Logical consistency in LLMs is essential to ensure consistent responses and prevent hallucinations, particularly during multi-step reasoning. To enhance the self-consistency inherent in Chain-of-thought prompting, [Wang et al. \(2023f\)](#) employs a knowledge distillation framework. They first generate a consistent rationale using contrastive decoding ([Li et al., 2022c](#)) and then fine-tune the student model with a counterfactual reasoning objective, which effectively eliminates reasoning shortcuts ([Branco et al., 2021](#)) that derive answers without considering the rationale. Furthermore, by employing contrastive decoding directly, LLMs can reduce surface-level copying and prevent missed reasoning steps ([O’Brien and Lewis, 2023](#)).

6 Challenges and Open Questions

In this section, we delve into the multifarious challenges and open questions surrounding hallucination in LLMs, aiming to guide future directions in this pivotal domain.

6.1 Challenges in LLM Hallucination

In the pursuit of reliable and truthful LLMs, addressing hallucination is essential, given its inher-

ent complexities. While significant strides have been made in mitigating LLM hallucinations, notable challenges still remain. In this context, we delve into these challenges, highlighting their manifestation in domains such as long-form text generation (§6.1.1), retrieval augmented generation (§6.1.2), and large vision-language models (§6.1.3).

6.1.1 Hallucination in Long-form Text Generation

Long-form text generation has gained widespread application in LLMs ([Qin et al., 2023](#); [Bhat et al., 2023](#); [Chen et al., 2023b](#)). However, as the length of the generated content increases, the propensity for hallucination also grows, leading to challenges in evaluating such hallucinations ([Min et al., 2023](#)). Firstly, existing LLM hallucination benchmarks ([Lin et al., 2022](#); [Cheng et al., 2023](#)) are usually presented in the form of factoid questions and answers, focusing more on factual hallucinations. There is a noticeable absence of manually annotated hallucination benchmarks in the domain of long-form text generation, which hinders researchers from studying specific types of hallucinations in this context. Secondly, evaluating hallucinations in long-form text generation is challenging. While there are some evaluation metrics available ([Min et al., 2023](#)), they have limitations and are not applicable when the facts are more nuanced, open-ended, and debatable, or when there are conflicts in knowledge sources. This poses obstacles for practical applications in real-world scenarios.

6.1.2 Hallucination in Retrieval Augmented Generation

Retrieval Augmented Generation (RAG) has emerged as a promising strategy to mitigate hallucinations in LLMs. As concerns around LLM hallucinations have intensified, RAG has increasingly come under the spotlight, paving the way for a range of commercial applications, such as Perplexity², YOU.com³ and New Bing⁴. By retrieving evidence from external knowledge bases, RAG enables LLMs to be equipped with up-to-date knowledge and generate responses conditioning on relevant evidence. However, despite its advantages, RAG also suffers from hallucinations. One notable issue is the potential for error accumulation within

²<https://www.perplexity.ai/>

³<https://you.com/>

⁴<https://www.bing.com/new>

the RAG pipeline. Irrelevant evidence can be propagated into the generation phase, possibly tainting the output (Li et al., 2023a; Shi et al., 2023a; Cho et al., 2023; Xu et al., 2023). Another concern lies in the arena of generative retrievals, which occasionally suffer from citation inaccuracies (Rashkin et al.; Liu et al., 2023f; Yue et al., 2023; Gao et al., 2023a; Chen et al., 2023a). While citations aim to offer a traceable path to the information’s source for validation purposes, errors in this domain can lead users astray. Furthermore, existing RAG may suffer from a trade-off between diversity and factuality (Liu et al., 2023f) which poses a new challenge in terms of the need for diversity.

6.1.3 Hallucination in Large Vision-Language Models

Enabling the visual perception ability, along with exceptional language understanding and generation capabilities, Large Vision-Language Models (LVLMs) have exhibited remarkable vision-language capabilities (Zhu et al., 2023a; Liu et al., 2023d; Yu et al., 2021; Huang et al., 2023b; Maaz et al., 2023; Chen et al., 2023e; Yu et al., 2023b; Zellers et al., 2019). Unlike previous pre-trained multi-modal models that gain limited vision-language abilities from large-scale visual-language pre-training datasets (Wang et al., 2022; Li et al., 2023b; Luo et al., 2020; Zhong et al., 2023a), LVLMs exploit advanced large-language models to better interact with humans and the environment. The consequent diverse applications of LVLMs also bring new challenges to maintaining the reliability of such systems, which therefore had to be further investigated and mitigated.

Li et al. (2023e), Lovenia et al. (2023), take the first step towards evaluating the object hallucinations in the LVLMs. Evaluations and experiments reveal that current LVLMs are prone to generate inconsistent responses with respect to the associated image, including non-existent objects, wrong object attributes, incorrect semantic relationships, etc. Furthermore, Liu et al. (2023c), Zong et al. (2023) and Liu et al. (2023b) show that LVLMs can be easily fooled and experience a severe performance drop due to their over-reliance on the strong language prior, as well as its inferior ability to defend against inappropriate user inputs. Current evaluations and discussions mainly focus on object hallucination. However, despite the witnessed perception errors, LVLMs can generate flawed logical reasoning results even when correctly recognizing

all visual elements, which remains to be further investigated.

Efforts have been made towards building a more robust large vision-language model. Gunjal et al. (2023), Lu et al. (2023), and Liu et al. (2023c) propose to further finetuning the model to produce more truthful and helpful responses. Another line of work chooses to post-hoc rectify the generated inconsistent content, such as (Zhou et al., 2023b), and (Yin et al., 2023). Though proved to be effective, those methods usually require additional data annotations, visual experts, or training phases, which prevent LVLMs from effectively scaling and generalizing to various fields. Thus, a more universal approach is expected in the future to build a more reliable system. What’s more, when presented with multiple images, LVLMs sometimes mix or miss parts of the visual context, as well as fail to understand temporal or logical connections between them, which might hinder their usage in many scenarios, yet properly identifying the reason for such disorders and tackling them still requires continued efforts.

6.2 Open Questions in LLM Hallucination

As research into LLM hallucination progresses, several questions demand ongoing discussion. These encompass the effectiveness of LLMs’ self-correction mechanisms in reducing hallucinations (§6.2.1), the understanding of knowledge boundaries within LLMs (§6.2.2), and the balance between their creativity and truthfulness (§6.2.3). Delving into these open questions paves the way for a more profound understanding of the capabilities of LLMs and the intricacies of hallucinations.

6.2.1 Can Self-Correct Mechanisms Help in Mitigating Reasoning Hallucinations?

While LLMs have shown remarkable capabilities in tackling complex reasoning tasks through Chain-of-Thought prompting (Wei et al., 2022), they occasionally exhibit unfaithful reasoning characterized by inconsistencies within the reasoning steps or conclusions that do not logically follow the reasoning chain (Golovneva et al., 2022; Ribeiro et al., 2023; Lyu et al., 2023). Research indicates that integrating external feedback into LLMs can significantly mitigate such hallucinations in reasoning. This feedback typically comes from external knowledge sources through retrieval processes (He et al., 2023; Gou et al., 2023), interactive debates with other LLMs (Du et al., 2023; Cohen et al., 2023),

or guidance from external evaluation metrics (Lei et al., 2023; Khalifa et al., 2023).

Nonetheless, a branch of research (Madaan et al., 2023; Yao et al., 2023b; Xie et al., 2023) explores the potential of self-correction mechanisms, where an LLM corrects its initial responses using its built-in capabilities, independent of external feedback. Although self-correction has shown promise for achieving faithful and accurate reasoning, especially in iterative settings, certain studies (Stechly et al., 2023; Huang et al., 2023a; Valmeekam et al., 2023) question the effectiveness of the self-correction mechanism, pointing out that LLMs still struggle to self-correct their reasoning chains. Consequently, the effectiveness of self-correction mechanisms in mitigating reasoning hallucinations remains an open question, which deserves further exploration.

6.2.2 Can We Accurately Capture LLM Knowledge Boundaries?

Despite the impressive capacity to capture factual knowledge from extensive data, LLMs still face challenges in recognizing their own knowledge boundaries. This shortfall leads to the occurrence of hallucinations, where LLMs confidently produce falsehoods without an awareness of their own knowledge limits (Pacchiardi et al., 2023; Ren et al., 2023; Zhao et al., 2023c). Numerous studies delve into probing knowledge boundaries of LLMs, utilizing strategies such as evaluating the probability of a correct response in a multiple-choice setting (Kadavath et al., 2022), or quantifying the model’s output uncertainty by evaluating the similarity among sets of sentences with uncertain meanings.

Furthermore, a line of work (Moschella et al., 2022; Burns et al., 2022; Li et al., 2023d; Azaria and Mitchell, 2023) has revealed that LLMs contain latent structures within their activation space that relate to beliefs about truthfulness. Recent research (Slobodkin et al., 2023) also found substantial evidence for LLMs’ ability to encode the unanswerability of questions, despite the fact that these models exhibit overconfidence and produce hallucinations when presented with unanswerable questions. Nonetheless, Levinstein and Hermann (2023) have employed empirical and conceptual tools to probe whether or not LLMs have beliefs. Their empirical results suggest that current lie-detector methods for LLMs are not yet fully reliable, and the probing methods proposed by (Burns et al., 2022) and (Azaria and Mitchell, 2023) do not adequately gen-

eralize. Consequently, whether we can effectively probe LLMs’ internal beliefs is ongoing, requiring further research.

6.2.3 How Can We Strike a Balance between Creativity and Factuality?

In the development of truthful and reliable LLMs, the challenge of balancing creativity and factuality stands out as a significant concern (Mukherjee and Chang, 2023; Lee, 2023). Ensuring factuality is critical for LLMs intended for real-world applications; any inaccuracies can mislead users and pollute the online environment. The repercussions of such misinformation could be significant, potentially snowballing and cascading into the data used for subsequent LLM training. Conversely, hallucinations can sometimes offer valuable perspectives, particularly in creative endeavors such as storytelling, brainstorming, and generating solutions that transcend conventional thinking.

While current research on LLMs leans heavily towards reducing hallucinations, it often overlooks the important role of their creative capacities. As LLMs continue to evolve, the challenge of striking a balance between their creativity and factual accuracy remains unresolved. It is also interesting to explore the balance not only in multi-modal text generation tasks (Li et al., 2023b; Yu et al., 2021) but also in vision generation tasks (Zhang et al., 2023b; Rombach et al., 2022). This issue goes beyond mere technicalities, necessitating a broader contemplation on the essence of artificial intelligence and its implications for human interaction and the exchange of knowledge.

7 Conclusion

In this comprehensive survey, we have undertaken an in-depth examination of hallucinations within large language models, delving into the intricacies of their underlying causes, pioneering detection methodologies as well as related benchmarks, and effective mitigation strategies. Although significant strides have been taken, the conundrum of hallucination in large language models remains a compelling and ongoing concern that demands continuous investigation. Moreover, we envision this survey as a guiding beacon for researchers dedicated to advancing secure and trustworthy artificial intelligence. By navigating the complex landscape of hallucinations, we hope to empower these dedicated individuals with invaluable insights that drive

the evolution of AI technologies towards greater reliability and safety.

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A Appendix

Method	Language	TruthfulQA			FacTool		ChineseFactEval	HalluQA
		True + Info	True	Info	Claim-level Acc	Response-level Acc	Manual	GPT-4 vote
GPT-4	en	-	-	-	75.6	43.33	183.5/301	53.11%
ChatGPT	en	78.46%	79.92%	98.53%	68.63	36.67	-	39.33%
Claude-v1	en	-	-	-	63.95	26.67	-	-
Bard	en	-	-	-	61.15	33.33	-	-
Doubao	zh	-	-	-	-	-	139/301	-
Yiyan	zh	-	-	-	-	-	122.5/301	69.33%
Sensetime	zh	-	-	-	-	-	103.5/301	-
ChatGLM-pro	zh	-	-	-	-	-	89.5/301	61.33%
ABAB	zh	-	-	-	-	-	77/301	56.00%
MPT-7B	en	29.13%	36.72%	92.04%	-	-	-	-
MPT-30B	en	35.25%	40.27%	94.74%	-	-	-	-
Falcon-7B	en	25.95%	29.01%	96.08%	-	-	-	-
Falcon-40B	en	40.39%	44.8%	95.23%	-	-	-	-
Llama-1-7B	en	27.42%	32.31%	94.86%	-	-	-	-
Llama-1-13B	en	41.74%	45.78%	95.72%	-	-	-	-
Llama-1-33B	en	44.19%	48.71%	95.23%	-	-	-	-
Llama-1-65B	en	48.71%	51.29%	96.82%	-	-	-	-
Llama-2-7B	en	33.29%	39.53%	93.02%	-	-	-	-
Llama-2-13B	en	41.86%	45.65%	96.08%	-	-	-	-
Llama-2-34B	en	43.45%	46.14%	96.70%	-	-	-	-
Llama-2-70B	en	50.18%	53.37%	96.21%	-	-	-	-
MPT-instruct-7B	en	29.99%	35.13%	94.37%	-	-	-	-
Falcon-instruct-7B	en	28.03%	41.00%	85.68%	-	-	-	-
Llama-2-7B-Chat	en	57.04%	60.59%	96.45%	-	-	-	-
Llama-2-13B-Chat	en	62.18%	65.73%	96.45%	-	-	-	-
Llama-2-34B-Chat	en	67.20%	70.01%	97.06%	-	-	-	-
Llama-2-70B-Chat	en	64.14%	67.07%	97.06%	-	-	-	-
Baichuan2-53B	zh	-	-	-	-	-	-	68.22%
SparkDesk	zh	-	-	-	-	-	-	60.00%
QWen-14B-Chat	zh	-	-	-	-	-	-	46.89%
Baichuan2-13B-Chat	zh	-	-	-	-	-	-	42.44%
Baichuan2-7B-Chat	zh	-	-	-	-	-	-	40.67%
Xverse-13B-Chat	zh	-	-	-	-	-	-	39.11%
Xverse-7B-Chat	zh	-	-	-	-	-	-	36.89%
QWen-14B	zh	-	-	-	-	-	-	36.22%
ChatGLM2-6B	zh	-	-	-	-	-	-	34.89%
Baichuan2-13B	zh	-	-	-	-	-	-	33.78%
Qwen-7B-Chat	zh	-	-	-	-	-	-	31.78%
Baichuan-13B-Chat	zh	-	-	-	-	-	-	31.33%
ChatGLM-6B	zh	-	-	-	-	-	-	30.44%
QWen-7B	zh	-	-	-	-	-	-	29.78%
Xverse-13B	zh	-	-	-	-	-	-	27.33%
Baichuan-13B	zh	-	-	-	-	-	-	25.33%
Baichuan2-7B	zh	-	-	-	-	-	-	25.33%
Baichuan-7B	zh	-	-	-	-	-	-	22.22%
Xverse-7B	zh	-	-	-	-	-	-	20.22%

Table 6: An overview of the performance of existing LLMs on hallucination evaluation benchmarks. For results in TruthfulQA, we directly used the results in Llama-2 Technical Report; as for ChineseFactEval and FacTool, we used the results in its GitHub repository and report. Regarding HalluQA, we directly used the results in its paper.