CSE584 Final Project Report:

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Abstract

This study examines the error recognition capabilities of prominent Large Language Models (LLMs) across a set of questions from the domains of Biology, Physics, Chemistry, and Astronomy. The analysis highlights significant performance disparities, with one model outperforming others in error detection while another, characterized by a smaller architecture, shows weaker capabilities. The introduction of explicit prompts noticeably enhances the models' error recognition rates, underscoring the importance of guided cues. Disciplinary variations were evident, with Biology questions being more successfully identified as erroneous compared to Chemistry. The findings underscore the potential of strategic prompt engineering and model refinement to improve LLMs' diagnostic abilities.

1 Introduction

In scenarios involving unsolvable queries, humans possess the ability to discern errors and solicit additional information to transform these queries into solvable ones. Conversely, our investigation indicates that this ability may be deficient in Large Language Models (LLMs), which endeavor to emulate human intelligence. To elucidate this phenomenon, we propose three pivotal research questions:

- $\mathcal{Q}_1$: What is the percentage of hallucination recognition exhibited by each model?
- $\mathcal{Q}_2$: Are there discernible discrepancies in model performance across different academic disciplines?
- $\mathcal{Q}_3$: Does modifying prompts—such as incorporating cues to verify the validity of the question—enhance the model's ability to identify hallucinations? (Analyze the percentage variation)

To address the aforementioned research questions, a dataset comprising 33 scientifically erroneous questions was curated, and five leading LLMs were selected. The LLMs employed in this study include GPT4, GPT4o, Llama3-8b (Llama3), GALACTICA-30b (GALACTICA), and Gemini-1.5-flash (Gemini) (OpenAI et al., 2024; Dubey et al., 2024; Taylor et al., 2022; Team et al., 2024). This selection consists of three proprietary models and two open-source models, utilizing two A100 GPUs. For the open-source models, default parameters—such as temperature—were maintained without alterations. Each model was tasked with resolving the problems under their default settings.

2 Related Work

Although substantial research has been conducted concerning hallucinations in Large Language Models (LLMs) and their problem-solving capabilities (Lee, 2023; Manakul et al., 2023; Feldman et al., 2023; Yao et al., 2024), the investigation into the models' ability to identify errors within problem statements remains relatively unexplored. Benchmarks designed to deceive LLMs using false beliefs and misconceptions, alongside the Faulty Math Word Problems dataset containing intentional errors to evaluate the error recognition capacities of leading LLMs, have been proposed, generating interest in this emerging research domain (Lin et al., 2022; Rahman et al., 2024). Our study aligns with this interest by encompassing an array of scientific disciplines.

Rahman et al. formulated intriguing research inquiries, such as the impact of hints on model performance (Rahman et al., 2024). The research questions posited in this report draw inspiration from this body of work. Distinguishing itself from previous studies, this experiment offers novelty by extending the analysis to multiple disciplines beyond mathematics.

3 Datasets

A total of 33 erroneous questions were curated from diverse sources spanning four disciplines: Biology, Physics, Chemistry, and Astronomy. While most questions are derived from original sources, they have been intentionally modified to incorporate errors. The sources are documented in the dataset's Google Sheet. The dataset includes both multiple-choice and open-ended questions, each presenting various types of errors, such as multiple-choice questions devoid of a valid answer choice, questions that contravene disciplinary norms, and questions lacking sufficient information.

3.1 No Answer in Options

This category of erroneous questions is of the multiple-choice type, offering selection choices that do not include the correct answer. Consequently, the model is tasked with identifying the absence of a valid answer.

Cats reproduce sexually, are diploid and have 38 chromosomes (n=19). Where do the chromosomes in a cat zygote come from? A. All 36 from each gamete. B. All 36 from an egg. C. All 36 from the mitotic division of a gamete. D. All 36 from a sperm cell. E. 18 from a sperm cell, 18 from an egg.

3.2 contradicts rules

Irrespective of the question format, this type of error question includes content that contradicts established disciplinary rules. For example, consider a physics problem presented to the model with the input that time equals -2, which is impossible. The model must detect and highlight such inconsistencies.

A cannonball is fired at an angle θ $upfromthehorizontalataspeedof$ v_o along level ground. A second cannonball is fired at the same speed, but at a different angle. Both cannonballs travel the same horizontal distance before landing, but one of the cannonballs takes -2 times as long to make the journey as the other. Find the two angles at which the cannonballs are launched.

3.3 Lack of Information

Questions within this category lack the necessary information to be solvable, preventing the model from making assumptions to derive solutions. This type includes questions that feature incorrect terminology, as exemplified below.

Which substance does not obey the Newton octet rule? (a) N2 (b) NO (c) CF4 (d) Ar

4 Results

For each model, they were first given just problems to solve them without further instructions. Table 1 shows percentage difference between LLMs when they were given questions only. Number of questions that has been recognized by LLMs were counted and divided by the total number of questions in the dataset. Using the same result, number of problems per discipline which was identified as faulty by the model were counted and shown as a bar diagram as shown on Figure 1.

	GALACTICA	Gemini	GPT4	GPT4o	Llama3
recognition	9.09	15.15	15.15	24.24	3.03

Table 1: Answer to Q_1: hallucination recognition percentage

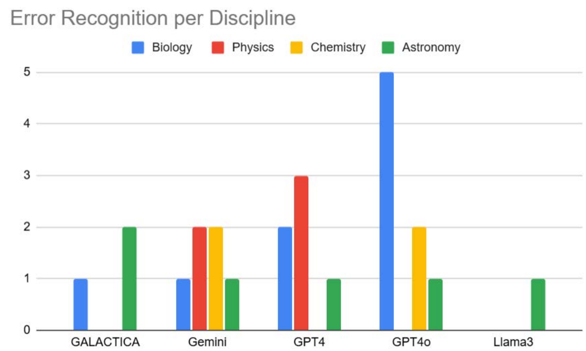

Figure 1: Answer to Q_1: Comparison of LLM performance across disciplines.

To compare the effect of hints, prompt were added with Faulty questions. Each versions of prompts are 1) without any hints just giving the question, 2) "Question might not be solvable.", and 3) "Make sure if the question contains error." Each prompt version results are represented in the Table 2.

	Prompt 1	Prompt 2	Prompt 3
GALACTICA	9.09	18.18	21.21
Gemini	15.15	48.48	84.85
GPT4	15.15	30.30	60.61
GPT4o	24.24	21.21	48.48
Llama3	3.03	12.12	12.12

Table 2: Answer to $\mathcal{Q}_3$: effect of prompt on performance (percentage)

5 Discussion

The responses generated by the Large Language Models (LLMs) exhibit various approaches when addressing questions. These approaches can be categorized as: (1) assuming the given question is error-free, (2) identifying possible typographical errors but auto-correcting them without explicit mention, (3) explicitly identifying errors in the question and subsequently resolving them, and (4) declining to provide an answer due to the identification of errors in the question. For the purpose of this analysis, responses categorized as (1) and (2) were considered to have been 'tricked' by the questions, whereas categories (3) and (4) were considered as 'not-tricked'.

An interesting observation was that some models reported insufficient information to solve certain problems, which is a logical deduction given that they were provided with erroneous data. This behavior was interpreted as successful error detection by the LLMs. When examining the performance results in Table 1, GPT4o demonstrated superior performance in recognizing faulty questions, while Llama3 exhibited the poorest performance in this aspect.

Furthermore, addressing our second research question $\mathcal{Q}_2$, Figure 1 elucidates discipline-specific recognition patterns. On average, only one question from the Astronomy discipline was accurately recognized. In contrast, Biology questions were the most frequently identified as containing errors throughout the experiment, while Chemistry questions had the fewest recognitions across the models.

The inclusion of hints significantly enhanced the models' error recognition capabilities, as evidenced by the results presented in Table 2. This finding aligns with prior research by Rahman et al. (Rahman et al., 2024), which also noted improved performance when models were pre-emptively alerted to potential errors. The prompt explicitly alerting the model to the presence of possible errors notably increased the error recognition rates across the experiments compared to other prompts.

A notable result was the consistently low performance of Llama-3 across all experiments. This is hypothesized to be attributable to its smaller size, possessing only an 8 billion token capacity, which may have influenced its limited ability to detect and process errors effectively.

6 Conclusion

This study aimed to explore the error recognition capabilities of Large Language Models (LLMs) across multiple scientific disciplines, highlighting the inherent challenges these models face when confronted with erroneous questions. Through the analysis of 33 curated questions from Biology, Physics, Chemistry, and Astronomy, contrasted across five prominent LLMs, we discovered notable disparities in error detection proficiency.

Our findings reveal that while LLMs are sophisticated in simulating human-like problem-solving capabilities, their ability to independently distinguish errors varies widely. GPT4o emerged as the most effective model in recognizing faulty questions, whereas Llama3 exhibited significant limitations, potentially tied to its smaller size. These variations underscore the importance of model architecture and capacity in influencing performance outcomes.

The experimental results further demonstrated that the incorporation of explicit prompts that signal potential errors substantially enhances model performance in error detection, as corroborated by previous research. This suggests that LLMs can benefit from augmented cues that guide their initial assessments of problem validity, highlighting an avenue for improving model training and deployment strategies.

Discipline-specific analysis clarified that Biology questions were the most frequently identified as erroneous, suggesting potential disciplinary biases or complexities that LLMs handle with varying efficacy. Conversely, Chemistry posed the greatest challenge, suggesting room for targeted improvements in model training across specific subject areas.

7 Limitation and Future Works

Limitation: This research gone through limited amount of dataset. Also, due to the time limitation, open sourced models size has to be small enough so performance on detecting error could be different with larger size models.

Future Works: With more dataset with various type of errors, it will be possible to have more detailed experiment to check which type of errors does the model identify better. Also, difficulty level of each problem can be one aspect that might affect model performance and would be a great research idea.

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