Research Update Presentation

Teaching Algorithmic Reasoning via In-context Learning

Jay Sudhir Chavan
a1936480@adelaide.edu.au

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Agenda Overview

Problem Statement

Teaching Algorithmic Reasoning

LLMs struggle with algorithmic reasoning due to a lack of understanding of the approach to a problem statement if it differs from their training. They are sensitive to prompting and formatting and fall behind in multi-step logical and algorithmic problem-solving.

Research Approach

Below is the approach I followed over the past week to gain a better understanding of the problem statement.

Paper Shortlisting

Shortlisted papers which are relevant to the problem statement on Microsoft Whiteboard to focus on main topic.

Summarizing papers

Read and summarized the shortlisted papers to create a better understanding of the current research and looking for potential solutions.

Presentation

Created a presentation to explain the key findings and future work that can be done to solve the problem.

Key Findings

After reading the papers, a common approach that I came across in a few of them was:

Improving the Prompting
LLMs are sensitive to prompting, so to help them better understand the task, we can refine the prompts. Several approaches were mentioned, including Algorithmic Structuring in Reasoning, Algorithmic Prompting, Chain of Thought, Tree/Graph of Thoughts, and Decomposed Prompting.

Improving the Transformer Architecture
The current architecture lacks certain properties, such as iteration. It can be improved by designing better architectures, like the Looped Transformer Architecture, which incorporates an iterative approach.

Improving the Training Data
Conventional data formats are inefficient for teaching arithmetic to transformers. Training on chain-of-thought-style data enhances accuracy and learning speed.

Next Steps and Future Work

Understanding Transformers in LLMs

Researching the current transformer architecture in LLMs and exploring ways to improve it in the context of algorithmic reasoning.

Experimenting with Prompting

Experimenting with various prompting methods to determine which yields better results, while comparing factors like computational costs and processing time.

Enhancing Training Data for LLMs

Investigating how training data can be improved for a solid foundation and to create accurate response.

Conclusion

Algorithmic reasoning in LLMs remains a challenging problem due to their limitations in understanding structured problem-solving, multi-step reasoning, and algorithm execution. Through my research, I identified three key approaches to address these challenges:

- Improving Prompting
- Enhancing Transformer Architecture
- Refining Training Data

Moving forward, further research is needed to optimize these approaches.

References

Zhou, H., Nova, A., Larochelle, H., Courville, A., Neyshabur, B. and Sedghi, H., 2022. Teaching algorithmic reasoning via in-context learning. arXiv preprint arXiv:2211.09066.

Chen, B., Zhang, Z., Langrené, N. and Zhu, S., 2023. Unleashing the potential of prompt engineering in large language models: a comprehensive review. arXiv preprint arXiv:2310.14735.

Zhao, W.X., Zhou, K., Li, J., Tang, T., Wang, X., Hou, Y., Min, Y., Zhang, B., Zhang, J., Dong, Z. and Du, Y., 2023. A survey of large language models. arXiv preprint arXiv:2303.18223, 1(2).

Giannou, A., Rajput, S., Sohn, J.Y., Lee, K., Lee, J.D. and Papailiopoulos, D., 2023, July. Looped transformers as programmable computers. In International Conference on Machine Learning (pp. 11398-11442). PMLR.

Espejel, J.L., Ettifouri, E.H., Alassan, M.S.Y., Chouham, E.M. and Dahhane, W., 2023. GPT-3.5, GPT-4, or BARD? Evaluating LLMs reasoning ability in zero-shot setting and performance boosting through prompts. Natural Language Processing Journal, 5, p.100032.

Lee, N., Sreenivasan, K., Lee, J.D., Lee, K. and Papailiopoulos, D., 2023. Teaching arithmetic to small transformers. arXiv preprint arXiv:2307.03381.

Testolin, A., 2024. Can neural networks do arithmetic? a survey on the elementary numerical skills of state-of-the-art deep learning models. Applied Sciences, 14(2), p.744.

References

Sel, B., Al-Tawaha, A., Khattar, V., Jia, R. and Jin, M., 2023. Algorithm of thoughts: Enhancing exploration of ideas in large language models. arXiv preprint arXiv:2308.10379.

Zelikman, E., Huang, Q., Poesia, G., Goodman, N. and Haber, N., 2023. Parsel🐍: Algorithmic Reasoning with Language Models by Composing Decompositions. Advances in Neural Information Processing Systems, 36, pp.31466-31523.

Manikandan, H., Jiang, Y. and Kolter, J.Z., 2023. Language models are weak learners. Advances in Neural Information Processing Systems, 36, pp.50907-50931.

Daull, X., Bellot, P., Bruno, E., Martin, V. and Murisasco, E., 2023. Complex QA and language models hybrid architectures, Survey. arXiv preprint arXiv:2302.09051.

Havrilla, A. and Iyer, M., 2024. Understanding the effect of noise in llm training data with algorithmic chains of thought. arXiv preprint arXiv:2402.04004.

Markeeva, L., McLeish, S., Ibarz, B., Bounsi, W., Kozlova, O., Vitvitskyi, A., Blundell, C., Goldstein, T., Schwarzschild, A. and Veličković, P., 2024. The clrs-text algorithmic reasoning language benchmark. arXiv preprint arXiv:2406.04229.

Pawlowski, N., Vaughan, J., Jennings, J. and Zhang, C., 2023. Answering causal questions with augmented llms.

Yin, Y. and Wang, Z., 2025. Are Transformers Able to Reason by Connecting Separated Knowledge in Training Data?. arXiv preprint arXiv:2501.15857.

References

Debnath, T., Siddiky, M.N.A., Rahman, M.E., Das, P. and Guha, A.K., 2025. A Comprehensive Survey of Prompt Engineering Techniques in Large Language Models. TechRxiv.

Wei, J., 2024. Towards Understanding Embeddings of Neural Network A Theoretical Perspective (Doctoral dissertation, The University of Wisconsin-Madison).

Ji, J., 2024. Integrate Learning and Reasoning for Large Language Model and Recommender Systems (Doctoral dissertation, Rutgers The State University of New Jersey, School of Graduate Studies).

Eskandari, F. and Roozbahani, Z., 2025. A review of prompt engineering methods in large language models. Engineering Management and Soft Computing, 10(2).

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Thank You

Jay Sudhir Chavan
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