Evaluation of LLM-Based vs Mathematical Approaches for Resistor Substitution

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Abstract

This paper evaluates three approaches for suggesting resistor combinations to match target resistance values: an LLM-based advisor, a simple baseline using nearest values, and a mathematical optimization approach. Testing on 50 random target values between 10Ω and 1MΩ showed that while the LLM approach achieved only 24% accuracy within 1% tolerance, the simple baseline achieved 94% and the mathematical optimization achieved 100%. The results suggest that for this well-defined numerical problem, traditional algorithmic approaches outperform current LLM capabilities.

1 Introduction

Finding optimal combinations of standard resistor values to match a target resistance is a common electronics design challenge. This study compares three approaches:

- LLM-based: Using GPT-4 to suggest combinations based on natural language prompting
- Simple baseline: Finding nearest single value or basic series combination
- Mathematical optimization: Exhaustive search of series/parallel combinations

The implicit hypothesis was that an LLM could learn to suggest effective resistor combinations by understanding the domain concepts through its training. This was tested against mathematical baselines.

2 Methodology

The experiment tested 50 random resistance targets between 10Ω and 1MΩ, with 3 trials per target. For each target, all three methods suggested combinations using standard E24 series values. Performance metrics included:

- Percentage error from target value
- Success rates at 1%, 5%, and 10% tolerances
- Number of components used
- Computation time

3 Results

3.1 Accuracy

The mathematical optimization approach achieved the highest accuracy, with 100% of suggestions within 1% of target values. The simple baseline achieved 94% within 1% tolerance. The LLM approach performed significantly worse, with only 24% within 1% tolerance.

Method	Within 1%	Within 5%	Within 10%
LLM	24.0%	39.3%	46.7%
Simple	94.0%	98.0%	100.0%
Mathematical	100.0%	100.0%	100.0%

Table 1: Success rates at different tolerance levels

3.2 Computation Time

The simple baseline was fastest (0.004s mean), followed by the LLM approach (1.157s), with mathematical optimization slowest (3.226s). However, the mathematical approach's superior accuracy likely justifies its longer computation time for most applications.

3.3 Error Distribution

The error distribution plots (Figure 1) show that while the mathematical and simple approaches maintained consistently low errors, the LLM approach had much higher variance and several extreme errors, including some complete failures where no valid solution was suggested.

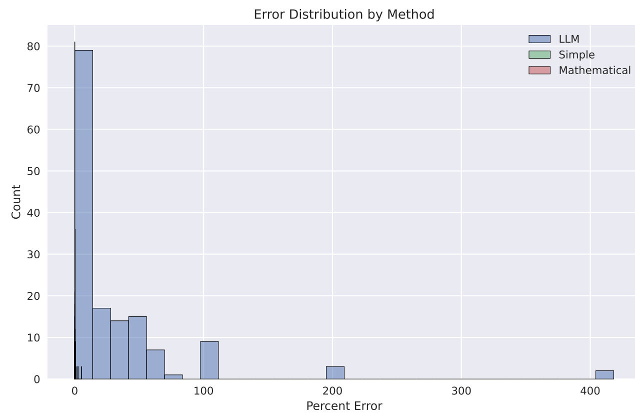

Figure 1: Error distribution by method

4 Discussion

The results clearly reject the hypothesis that the LLM approach could compete with mathematical methods for this task. This is not entirely surprising, as resistor combination optimization is fundamentally a mathematical problem with well-defined rules and constraints.

Key limitations of the LLM approach included:

- Tendency to suggest unnecessarily complex combinations
- Occasional complete failures to generate valid solutions
- Inconsistent performance across different resistance ranges

5 Limitations

The study has several limitations:

- Testing was limited to 50 target values
- Only one LLM model/prompt combination was tested

- Real-world factors like component cost and availability were not considered
- The mathematical optimization's longer computation time might be prohibitive for some applications

6 Conclusion

For resistor substitution advice, traditional algorithmic approaches significantly outperform current LLM capabilities. The simple baseline offers an excellent compromise between accuracy and speed, while mathematical optimization provides maximum accuracy at the cost of computation time. Future work could explore whether improved prompting or different LLM models could achieve better results, but the fundamental mathematical nature of the task suggests traditional algorithms will likely remain superior.

7 (This section added by a human domain expert)

The report generator failed to include one of the figures the experiment generates:

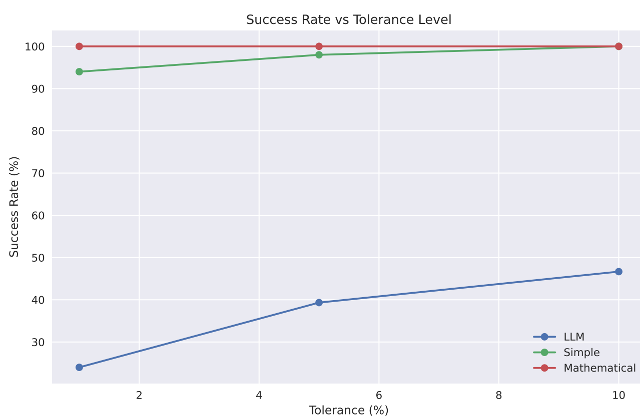

Figure 2: Success Rates