Peer Review of the Intermediary Report

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1 Introduction

The introduction is excellent, it clearly and consistently explains the project goals and methods used.

We don't quite understand why you mentioned a 4x4 grid, as all the boxes appear to have 7 columns and 4 rows of switches. However, this will not affect the model development, as the three columns on the left side of the device with the smallest values are negligible; their resistances are smaller than the offset and are of the order of the measurement error (around 0.2 Ohms).

2 Statistical and theoretical models

The section on statistical modeling is clear, presenting the initial model with three coefficients to represent linear contributions from each inductance. The need for interaction terms is well-justified here, as the report provides evidence that simple additive models fall short when predicting resistance with both switches on.

The authors have obtained the same data and handled the error of around 0.2 Ohms in the same way we did.

It's not entirely clear why the on-on combination was excluded in the first experiment matrix, especially since it was included later. It seems that testing the on-on combination was recognized as necessary from the beginning.

The explanations of variance, error calculations, and proof of zero collinearity are well done.

The variance graph should normally curve downward between the experimental points due to the high precision between them (an analogy: the point between four lamps is the most illuminated).

All the data tables present information clearly and understandably, making them easy to follow.

It's well-demonstrated that only two combinations are problematic, and the correct prediction was made: all the n-switch combinations simply add all the resistances except for the two problematic combinations (1-2 and 3-4 for each column).

We would also recommend to use graphs to demonstrate why it is better to use model with interaction and how significant are the differences.

The circuit diagram is a valuable addition, illustrating how each resistance and switch contribute to the system.

3 Link between models

It is stated: "Clearly, the theoretical model is far more robust than the empirical one. The main drawback of the empirical model is its inability to make predictions beyond the data already measured, which limits its practical utility".

However, using the empirical model, we can indeed make predictions beyond the data already measured:

$$y = a_0 + a_1x_1 + a_2x_2 + a_{12}x_1x_2 + a_3x_3 + a_4x_4 + a_{34}x_3x_4 + \text{similar terms for other columns.}$$

To predict the resistance of any possible combination of switches in the entire device (with 7 columns and 4 rows), which totals $C_n^k = \sum_{k=1}^{n} \frac{n!}{k!(n-k)!} = 2^n - 1\Big|_{n=28} = 268{,}435{,}455$ combinations, we only need to measure the resistances of each individual switch. This requires $7 \times 4 = 28$ measurements (plus one for the offset), along with the 2 nonlinear interactions per column, which adds $2 \times 7 = 14$ additional measurements. Thus, only 43 measurements are needed to predict the resistances for all 268,435,455 combinations.

It is stated that, in contrast, the theoretical model provides immediate predictions of interactions for any combination of two switches. However, this claim is also unclear for the following reasons:

- For any chosen pair of switches, four measurements are still needed to calculate the four resistances in the circuit. Thus, no immediate prediction is possible here, similar to the empirical model.
- Knowing the resistances for one measured pair does not enable us to infer the resistances for any other pair, meaning predictions for unmeasured pairs are not possible. This limitation also applies to the empirical model.
- To predict all combinations, it is necessary to measure each individual resistance along with the common resistances of the nonlinear pairs, enabling calculation of the circuit resistances in the theoretical model. Therefore, the theoretical model requires the same 43 measurements as the empirical model to make predictions across all combinations.

Consequently, the predictive power of the two models is equivalent. The primary difference is that the theoretical model explains the underlying physics of the system, whereas the empirical model only provides a calculation for the output.

In your comments, you mention that if the number of switches and resistances were significantly higher, developing a theoretical model would likely have been impossible. However, it is indeed possible to develop a theoretical model for any number of switches and resistances (otherwise, this would mean that the system of switches and resistances does not behave as a system of switches and resistances, which is a contradiction). You are correct in noting, though, that if no recurring pattern exists within the combinations, we would need as many resistances as there are combinations. This approach, however, would be impractical and lead to overfitting, resulting in what is sometimes referred to as a "just-so" model.

Finally, it would be advantageous to establish a formal link between the two models by deriving the coefficients of the empirical model using the resistances from the theoretical model. This approach would rigorously demonstrate their correspondence.

4 Conclusion

The authors outline clear next steps for expanding the model to more complex switch combinations, demonstrating foresight and an understanding of the project's future direction.

Good use of the appendix—it's effective that the bulky tables are collected there and don't stretch out the main sections.

The report is thorough and demonstrates a well-structured approach to empirical and theoretical modeling, There is still significant potential for developing the link between the two models. The report provides a foundation for further development of the model describing the entire device's resistance behavior.