Interpreting power analysis via agent-based models

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1 Rationale

Agent-based models (ABMs) simplify complex systems into individual agents that interact with one another and their environment. This helps us grasp how the system functions. But what is the advantage of this approach? We need to identify how ABMs can improve data analysis and interpretation in ways that other methods can't.

We propose following the "embrace, extend, and innovate" approach. First, make an ABM that replicates an existing model or method. Then, agentize a small part making the least possible change. Finally, after gaining confidence in the effects of agentization, we can agentize the original model further, in ways that traditional methods can't.

This approach suits cases where other models, such as equation-based, simulation-based, or regression-based models, are already well-established and understood. In these cases, the ABM's contribution will be clearer to experts in the field.

We're currently working on a project where we use ABMs to enhance our comprehension of a real-world experiment. The objective is to use a well-understood statistical workflow and agentize a small part of it in a way that merges well with the original statistical methodology. However, the plan is to show that through the agentization we can better use ancilliary data and knowledge that the standard statistical method just overlooks. This will improve our understanding of uncertainties and the overall statistical comprehension of the experiment.

The real-world experiment we're looking into is fairly straightforward: a hotel chain wants to cut down on food waste at its buffet tables by testing the effectiveness of different messages. They've designed two potential messaging strategies to reduce food waste among guests and plan to determine which one is more successful at minimizing waste in their nine hotels. Over a ten-week period, they'll run the experiment, switching messages at their hotels. Their goal is to figure out which hotel should display which message each week, to ensure that the messaging's impact on food waste is accurately estimated. In other words, they want to identify which experiment setup and subsequent statistical analysis yield the highest statistical power and are most likely to reveal the "true" effect of messaging on food waste.

2 Statistical Workflow

Eight hotels participate in a food waste experiment with two potential messages for guests. We want to know which message works best and how much it reduces food waste. The hotels vary in guest numbers and types each week, especially during peak tourist seasons in May and June. Hotels measure food waste once a day by weighing all leftover food on plates. Due to these complexities, we can't just calculate the statistical power from tables. Instead, we simulate the experiment and analysis in a non-agent-based format and bootstrap its properties.

The ideal experimental setup would be to randomly selecting a message for each hotel daily. This, however, was deemed logistically impossible. We presented instead several "second best" options to the hotel chain to balance statistical power and logistical costs.

We created an online web page for hotel managers to experiment by simulating different experimental setups. They could adjust factors such as the number of participating hotels, experiment duration, missing observations, and prior assumptions about the messaging's "true" effect on food waste. Managers could also test various experimental conditions and analysis methods.

The experimental setup options were:

1. Randomize the message daily for each hotel
2. Change the message for all hotels each month
3. Initially display no message, then divide hotels into two groups, alternating messages monthly
4. Same as above, but with three groups, one as a control
5. A diff-in-diff setup with three groups (two messages and a control) but no alternation

The web page and underlying simulation helped hotel managers balance statistical power and logistical constraints. They chose strategy three (two groups, alternating messages).

The statistical simulation supporting the web page uses a standard, non-agent-based model. Each simulated day, we draw guest numbers from a distribution. The total number of guests is converted into total waste using a lognormal distribution, then modified by the assumed true effects of messaging on food waste. After collecting simulated data, we perform regression and collect its coefficients. By repeating this simulation many times, we can compute statistical power and regression coefficient biases simply by analyzing for how many simulations the true effect of messaging was detected correctly. This represents the "embrace" stage of the analysis, where we replicate the best available science.

3 Agentization

As stated earlier, we aim to agentize only a small part of the entire statistical framework. As seen in figure 1, we plan to replace only the food waste generation part of the simulation. Currently, given the total number of guests and the

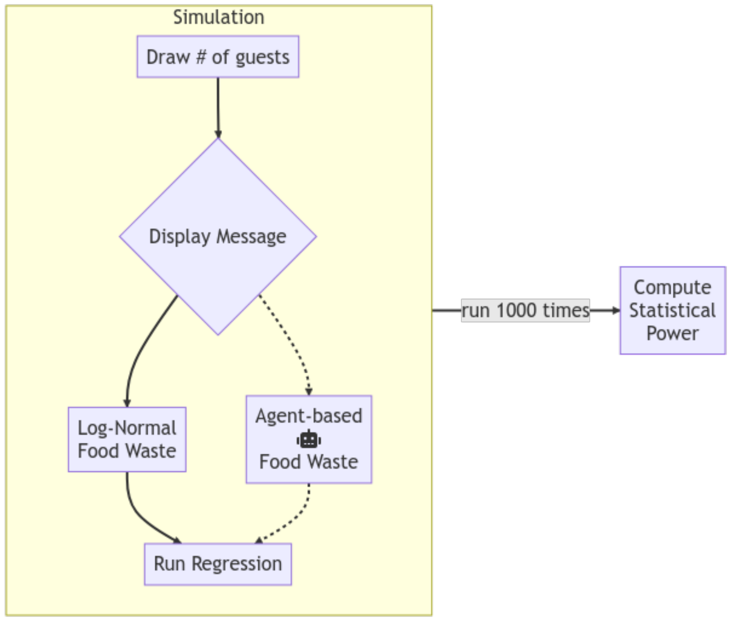

Fig. 1. How the agent-based model fits and compares to the usual diagram

displayed message, the simulation draws food waste per guest from a lognormal distribution. We will replace this with an agent-based model using the same inputs (total guests and message) and outputting the same result (total food waste). The overall statistical method remains unaffected by how the food waste is generated, making it simple to insert an agent-based model in place of the log-normal distribution.

The benefit of an agent-based model is its ability to use other types of information not easily incorporated into the broader statistical framework. For instance, we have qualitative data on guest types at the hotels, food types displayed, breakfast buffet hours, group sizes at the buffet, and theoretical knowledge about social norms and the social dynamics influencing personal food waste. While this data is either qualitative or just not collected frequently enough to inform the statistical regression, it can still be used by the agent-based model to simulate food waste generation more accurately.

In the context of the overall statistical framework, food generation simulation can be viewed as a black box. Whether it's produced by a random draw or an agent-based model, the overall procedure remains the same. The way we compute statistical power and bias remains unchanged. This will make the marginal effect of the agent-based model more clear.

The model is currently in development and will be ready for presentation at the social simulation conference we're submitting to by September.

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