Large-scale Agent-Based Modeling of Counterterrorism Efforts: Visualization and Empirical Model Evaluation

Natalie Ayers and Nick Gondek

Introduction

We developed an analytic toolkit for evaluating simulated terrorism scenarios with the goal of allowing researchers to generate novel hypotheses of counterterrorism effectiveness. We first developed an agent-based model of counterterrorism efforts and citizen reactions which can be run both locally and on GCP as a cloud function, and we developed a React dashboard to visualize the progression of each simulation. We further implemented a large-scale analysis of 2,700 simulations with unique parameter combinations run using MPI on UChicago's Midway2 cluster.

As an example of analyzing the results of these models, we compared the distribution of monthly attacks in each model with the distribution of monthly attacks in Israel and Palestine using a non-parametric statistical test. Finally, we developed a version of the simulation which allows for parameter changes mid-run, which would allow researchers to determine the effectiveness of reactive policy changes and enable further statistical analyses such as bias investigation in regression discontinuity models.

Background

In a 2012 paper, Laura Dugan and Erica Chenoweth developed a dataset of government counterterrorism actions and analyzed their impact on terror attacks, seeking to determine which government policies might be effective at reducing incidents of terrorism. Given the complex environments in which terrorism occurs, it will be useful to researchers to examine additional characteristics and actions which also may impact terrorist attacks and for which there may be policy solutions. One way to potentially identify some of these other useful avenues for research is through simulations of an agent-based model of terrorism and counterterrorist actions. By tuning parameters of models which are shown to be a relatively good representation of real behavior, new mechanisms may be identified that can then be tested empirically.

Methodology/Approach

We first refined a previously-generated model which represents citizens with the potential to become terrorist actors and a government which performs counterterror actions. Using the Python package Mesa, we developed this model to incorporate multiple parameters which may impact the lives and drives of citizens and government leaders, with the full acknowledgement that the model is an extreme simplification. The most important parameters which we included were: (a) the probability of committing a violent act, (b) government counterterror policy, (c) government reactivity to violence, (d) citizen discontent, (e) citizen starting population.

The base version of the model is designed to be run either locally or as a cloud function on Google Cloud Platform. Either version requires setting the desired parameters, and both output multiple data frames containing information on the actions of all citizens and governments throughout the simulation. This data can then be incorporated into an interactive javascript-based React dashboard, which allows for flexible playback of important model dynamics using Plotly visualizations including:

1. Heatmap denoting non-violent sentiment as color, overlaid with number of active combatants and arrows indicating government repression (down) and conciliation (up)

2. Pie chart of the other agents' sentiment at each time step

3. Line charts of the number of agents vs number of cumulative attacks, and cumulative government actions

Ideally, the parameters for a model could be set using this dashboard, the specified simulation could be run using the GCP cloud function, and the results of the simulation would be returned to the dashboard to visualize. However, due to a permissions issue which our student GCP accounts didn't have the ability to adjust (granting 'CloudInvoker' permissions to web requesters), we instead rely on users to call a python script to create new simulations as described in the project README.

After enabling this examination of individual simulations, the final component of our analysis was to examine a wide range of simulations, each representing a unique parameter combination, and determine which simulations might be the most fruitful for researchers to consider. We decided on a representative range of parameter values for each of the important model components discussed above and created versions of the simulation with every combination of these parameter values. These simulations were run in an embarrassingly parallel implementation using MPI across 15 nodes on the University of Chicago Midway 2 Research Computing Cluster in 4.9 hours.

We evaluated the simulations by comparing the distribution of the normalized count of monthly attacks in each simulation with the normalized count of monthly attacks from 1987-2004 in the Israeli-Palestinian terror attack dataset used by Dugan and Chenoweth (2012). Since these values are not normally distributed, we employed a non-parametric statistical test, the Kolmogorov-Smirnov test, to analyze the similarities between the real-world data and each of our simulations.

Results

The Kolmogorov-Smirnov analysis found 47 models were similar to the real-world distribution at the 0.01 significance level. These 47 models constitute a strong starting point for further analysis, such as examining the similarities between the parameters in these models. For example, all 47 models had the lowest level of government reactivity to violence, which is a parameter distinct from their general counterterrorism policy and which determines how likely governments are to react harshly in the wake of violence. After further computational analysis of the difference between government policy and government reactivity, a researcher could subsequently begin to examine this phenomenon and any insights using empirical data.

Discussion

Agent-based modeling is not currently widely used for studies of terrorism at the country-level, though social scientists are beginning to employ it again - after a period of decline - for use cases such as Bear Braumoeller's research into international order and conflict and Alex de Sherbinin's climate migration modeling. We hope our research follows in these examples for the use case of counterterrorism effectiveness by exploring different strategies for use cases of agent-based models which don't require the kind of precise, predictive capabilities which are likely unattainable and constitute some of the major criticisms of modeling.

In the future, we hope to expand the capabilities of the model by incorporating geographic components, fine-tuning the performance of existing parameters, and incorporating new parameters. We also developed a version of the model which allows for mid-simulation parameter change - such as were a government to change its counterterrorism policy or were new leadership to come to power. We believe using this capability to perform regression discontinuities on simulations which are varied by a single parameter could enable additional insight into the importance of certain characteristics.

References

Dugan, L., & Chenoweth, E. (2012). Moving Beyond Deterrence: The Effectiveness of Raising the Expected Utility of Abstaining from Terrorism in Israel. American Sociological Review, 77(4), 597–624. https://doi.org/10.1177/0003122412450573