Beyond Point Estimates: Operational Synthesis and Data Farming

Dr. Gary E. Horne
The MITRE Corporation

Overview

A methodology called *Operational Synthesis* [1], originated by Dr. Alfred Brandstein, is being developed at the Marine Corps Combat Development Command to explore questions using a synthesis of both new and existing methods of simulation and decision support. This research is proceeding under the umbrella of the multi-faceted US Marine Corps *Project Albert* that has the ultimate goal to develop better maneuver warriors. Along the way to achieving this end, we are attempting to develop new tools to capture emergent behavior in synthetic environments.

In particular, we utilize *Data Farming* [2] to examine questions. This meta-technique is made possible by recent technical advances in:

- complex adaptive systems models, which have the promise of capturing the aspects of adaptability, nonlinear interactions, feedback, and self-organization,
- computing power which enable us to generate the large volume of data needed to adequately represent vast spaces of possibilities, and
- our ability to organize, synthesize, and visualize scientific data.

We have focused our Data Farming efforts on computer models we refer to as "distillations" that ideally have the following four characteristics: transparency, speed, ease of configurability to the question at hand, and requirement of little training to use. Data

Farming is designed to capture and help us understand emergent behavior in these synthetic environments.

Within Project Albert we seek to explicitly represent and deal with nonlinearity, intangibles, and cooperative and competitive coevolution. Over time and within Operational Synthesis our goal is to apply Data Farming to maneuver warfare questions. Project Albert includes sub-projects to develop and apply a series of new models, multidisciplinary teams, and the scientific method to explore, and seek robust answers to, questions relevant to Marine Corps organization, equipment, tactics, and doctrine. Some of the many sub-projects within Project Albert are outlined in [3].

Some questions that we are attempting to seek insight into with these new methods, models, and capabilities are:

- When is decentralized (vs centralized) command and control desired or preferred?
- When should firepower (vs. maneuver) be used in a given tactical situation?
- What is the role of trust, or other so-called 'intangibles', on the battlefield? [4]

Of course, there are many other questions which are of interest to us, but these are but a few of the ones we have attempted to model and address directly. Our approach explores these types of questions from the perspective of the 'whole', vice from the perspective of the component parts. And finally, as the title of this article implies, the desire in all of our efforts is to go well beyond point estimates, because the understanding we seek requires much more.

Operational Synthesis

Operational Synthesis seeks to integrate across the spectrum of existing methods of simulation and decision support. It is our

attempt to utilize all of the tools available to us in order to explore and gain insight into a question of interest. Specifically, the tools we seek to synthesize are distillations, deterministic models (equations), higher-fidelity simulations, and wargames/exercises. These four tools run the gamut on many spectrums: human-in-the-loop/automated, stochastic/deterministic, high-fidelity/low-fidelity, to name a few. Further, each one of these tools has its own set of pros and cons.

Distillations have the pros of being simple and easy to use and run many times, are transparent, fun, and are able to capture nonlinearities, binary events, sensitivity to initial conditions, and coevolution. However, its cons are that they are often too simple to enable reasonable emergent behavior, and the enormous amount of data produced presents a significant problem with regard to sampling and visualization.

Higher-fidelity simulations are useful in that they produce a high-fidelity sample, e.g. cases where weather and time of day matter to a battle outcome would be explicitly represented. Also, experimental data that we have from real operations and exercises may contribute to the correct setting of parameter values. However, among other things, these simulations suffer from the inability to reproduce all possible outcomes because of being bogged down with so much detail for an individual case.

Deterministic models such as equations are appealing because they are concise and accurate, and do apply to many aspects of the military domain, such as the physics of trajectories, detection, etc. However, they are often applied to parts of the domain without much reason or validation beyond appealing to an analyst's background. Also, unfortunately, closed form solutions are rare, and the use of equations attempts to impose the mathematical constraints of a function on a particular situation, when really only a relation exists.

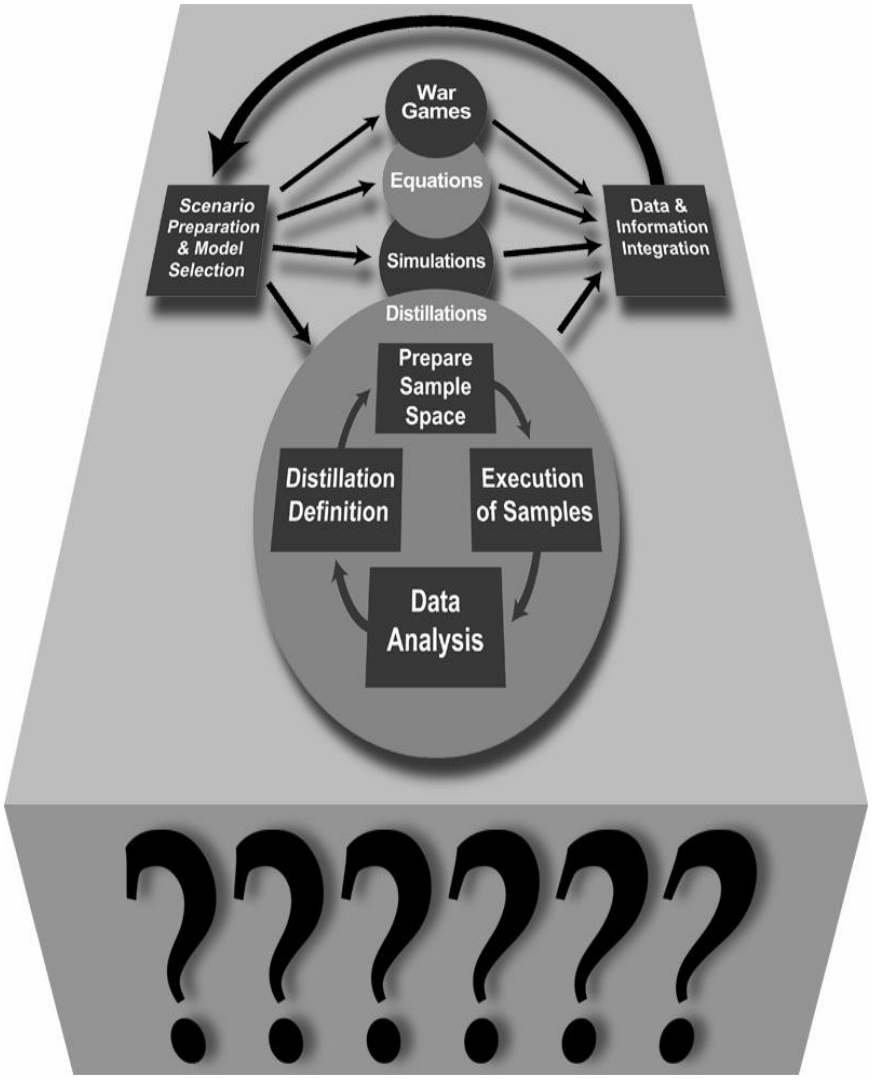
Finally, wargames/exercises are useful because they provide a common tableau for discussion and enhances mutual understanding of possible occurrences. However, they do not result in repeatable results (bad from an analytic standpoint), they are often dominated by personalities, and they often result in the use of an unrealistic scenario and exploration of limited options.

The goal of Operational Synthesis is to use the individual tools for what each is good for, and to put them all together in a way that synthesizes the wealth of information and knowledge which is gained by utilizing each of them. We are currently developing a methodology for interfacing distillations and higher-fidelity simulations. Also, a new command and control environment, which makes use of the tools as well as other aspects of decision support, is under development.

This application is a collaborative effort we have with the Swedish Armed Forces, in which we will pursue the creation of a new type of command and control (C2) environment called Red Orm. [5] The objectives of this project are to incorporate the nonlinearities of warfare, intrinsic human characteristics of warfare, cooperative and competitive co-evolution, crisis-space uncertainty and complexity, multi-dimensional reasoning, and time criticality into a collaborative C2 environment.

In summary, Operational Synthesis is a concept allowing for attempts to synthesize information from multiple tools to answer questions involving one or more of the phenomena of nonlinearities, intangibles, or coevolving landscapes. Data Farming is the mechanism by which we are implementing the concept of Operational Synthesis within Project Albert and is described in the next section. The figure below depicts Operational Synthesis and Data Farming. In the figure the circles represent the tools described earlier. Given the tools, Operational

Synthesis can be thought of as the "What" and Data Farming as the "How" of the squares and arrows in the figure. Finally, the reason or the "Why" for both the concept and the mechanism is represented by the questions that are the basis for our explorations.



Data Farming

Data Farming was first developed and used at the Marine Corps Combat Development Command in late 1997. It can be thought of as nothing more than putting the advances mentioned earlier to work to engage the scientific method. The metaphorical basis for the moniker *Data Farming* is strong, and reference [6] contains the details. We will let the reader refer to that publication for the details in this vein, other than to say that critics and supporters alike seem to find some fun in the *fertilize*, *cultivate*, *plant*, and *harvest* supporting metaphors when *growing* data is discussed.

A succinct summary of what Data Farming provides is a never-ending opportunity to explore our questions as depicted above in the figure. The idea is to grow more data in the areas of interest. This growth within a particular definition of a particular distillation might be in the form of more runs or a different preparation of the sample space to include different parameters, finer gradations of parameter values, or greater ranges. After the execution of samples and analysis using data visualization and search methods, the data farmer is free to grow more data in interesting areas, integrate with information from other tools, prepare a different scenario using the same distillation, select another distillation, or any combination of these possibilities that he or she thinks might lead to progress on the question at hand or new questions that arise in the Operational Synthesis.

In the figure, the distillation circle is larger because that is where we have concentrated our efforts to date and it seems to be an area that the military operations research community has only begun to explore. Also the four basic characteristics of distillations (transparent, fast, easily configurable to the question, easily applied with little training) make them “embarrassingly” amenable to Data Farming. Of course, Data Farming is applicable to any of

the four tools of military operations research listed and in fact to any science.

References

[1] Dr. Alfred Brandstein, *Operational Synthesis: Supporting the Maneuver Warrior*, briefing presented at the United States Coast Guard Academy, New London, Connecticut, 12 February 1999.

[2] Dr. Gary E. Horne, *Data Farming: A Meta-technique for Research on 21st Century Questions*, briefing presented at the Naval War College, Newport, Rhode Island, 13 November 1997.

[3] Dr. Alfred Brandstein, *Operational Synthesis: Applying Science to Military Science*, Phalanx, Vol 32 Number 4, December 1999.

[4] Dr. Gary Horne and Capt Mary Leonardi, "Trust on the Battlefield: Exploring Questions with a New Tool," *Maneuver Warfare Science 1998*, Marine Corps Combat Development Command Publication.

[5] Dr. Henrik Friman, and Dr. Gary Horne, "Project Albert + ROLF 2010 = Red Orm" *Maneuver Warfare Science 2001*, Marine Corps Combat Development Command Publication.

[6] Dr. Alfred Brandstein and Dr. Gary Horne, "Data Farming: A Meta-Technique for Research in the 21st Century," *Maneuver Warfare Science 1998*, Marine Corps Combat Development Command Publication.