2015

Representing Uncertainty of Hierarchical and Response Surface Models to Improve Design of Experiments

Lucas, Tom; Sanchez, Paul; Pav, Russell; Hamrick, Tom; Kelton, David; McDonald, Mary; Upton, Steve

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL

NAVAL RESEARCH PROGRAM

MONTEREY, CALIFORNIA

REPRESENTING UNCERTAINTY OF HIERARCHICAL AND RESPONSE SURFACE MODELS TO IMPROVE DESIGN OF EXPERIMENTS

by

Principal Investigators: Professor Tom Lucas and Dr. Paul Sanchez

Other Researchers: LT Russell Pav, Tom Hamrick, David Kelton,

Mary McDonald, Steve Upton

GSOIS

1 OCT 2014 – 31 MAR 2015

Prepared for: OPNAV N98

Mr. Vic Steinman and Mr. Chris Marsh

FY15 Mid-Year Report

Problem Statement: The Navy uses families of models of varying detail and focus to analyze forces and operational concepts. The information gleaned from these model-supported studies helps shape what the future Navy will look like and how it will fight. The current practice in the higher-to-lower-fidelity sequence of modeling is to use point estimates of more focused higher-fidelity model outputs as the inputs for the broader lower-fidelity models. It is vitally important to understand how these lower-level model errors are propagated through the series of models and how decisions are affected as a result. This research is reviewing previous efforts related to propagating errors in hierarchical models, empirically exploring the impacts of multiple approaches, and providing recommendations on extending and applying the methods—which will include uncertainty analysis, design of experiments (DOE), and preferred metamodel forms.

Process and Research Objective: The primary objective of this effort is to assess existing approaches for propagating errors in hierarchical combat models and recommend what the Navy should use in future studies. In particular, we want to empirically quantify how accurate various error propagation approaches are in estimating campaign-level measures and the variability associated with them. Through extensive experimentation, we will evaluate the effectiveness of various DOE techniques and metamodel forms in capturing and propagating errors in an ASW model hierarchy. We will determine if the classic assumptions are appropriate for the models and scenarios the Navy is using—and, if not, how robust the various approaches are to departures from the assumptions.

Ongoing Progress and Findings: Our analysis is focusing on a scenario in the South China Sea around 10 years in the future. Specifically, we will analyze the error propagation methodologies in the assault phase of the U.S. attempting to break a hostile submarine screen to gain access to the South China Sea. Our low-resolution campaign model is an already completed numerical implementation of a networked heterogeneous stochastic Lanchester model and salvo equations. Our primary MOE is the percent of time that U.S. forces can sufficiently attrite all threat undersea forces. Our mission-level simulation is under construction in the agent-based, time-step simulation environment Map Aware Non-uniform Automata (MANA). The MANA runs will provide distributions of outcomes (e.g., probability of detect, time to detect, Prob of kill | detection, etc.) for a variety of ASW performance measures. Once we have the family of models built and the data collected, we can choose factors to vary, and their ranges, as well as specific output measures. We can then run the models a large number of times to develop an accurate estimate of "ground truth." Given that, we will look at a host of error propagation (e.g., mean, bootstrap, bootstrap with synchronization, etc.) and metamodel approaches to quantitatively assess how well they do.

Recommendations: This project's results will be used by OPNAV staff and others in the Navy to help shape what the future Navy looks like and how it will fight. While we are still in early stages, we plan to be able to advise on how well multiple DOE and error propagation techniques work in estimating campaign-level measures and the associated uncertainties.