CLINICAL PAPER

Operations Research Department
Naval Postgraduate School

EFFICIENT SEARCH STRATEGIES IN HIGH-DIMENSIONAL COMPLEX MODELS

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CONTEXT

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• AS AN AID TO DECISION-MAKING, THE U.S. ARMY USES COMPLEX SIMULATIONS WHICH CONTAIN MUCH UNCERTAINTY.

• CONDUCTING A FULL-FACTORIAL DESIGN OF EXPERIMENT IS NOT FEASIBLE SINCE:

"2^{100} IS FOREVER!"

• VECTOR-IN-COMMANDER (VIC) MODEL HAS OVER 100,000 FACTORS.

• HOW CAN MAIN EFFECTS AND CRITICAL INTERACTIONS BE EFFICIENTLY IDENTIFIED IN COMPLEX MODELS?

BACKGROUND

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"TRADITIONAL" EXPERIMENTAL DESIGNS
BOX/HUNTER/HUNTER (1978), HICKS (1993)

EXPERIMENTAL DESIGNS IN COMPUTER SIMULATIONS
JACOBY/HARRISON (1962), HUNTER/NAYLOR (1970),
KLEIJNEN (1975), BILES (1979), WELCH ET AL (1992), BATES ET AL (1996),
LAW / KELTON (1999)

FACTOR SCREENING METHODOLOGIES

GROUP SCREENING
DORFMAN (1943)

SEQUENTIAL BIFURCATION
BETTONVIL/ KLEIJNEN (1996)

LATIN SUPERCUBE SAMPLING
OWEN (1998)

SUPERSATURATED DESIGNS
YAMADA/LIN (1999)

COMMON ASSUMPTIONS

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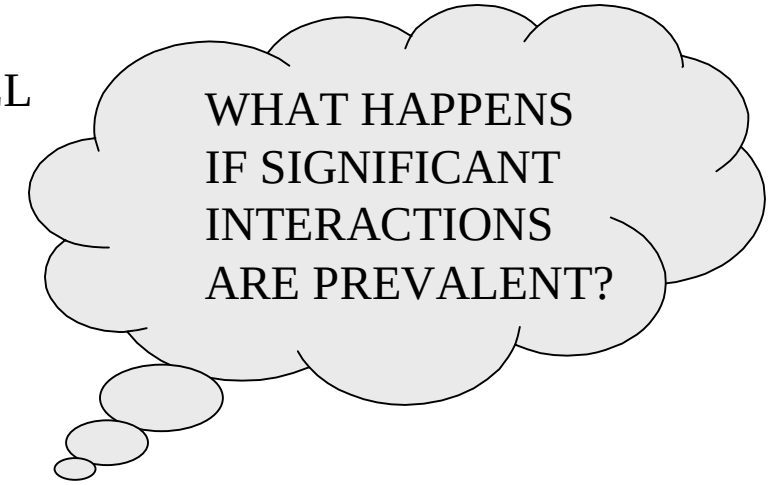
• OUT OF A VERY LARGE NUMBER OF VARIABLES, ONLY A SMALL NUMBER ARE IMPORTANT

• EACH OF THE VARIABLES HAS ONLY A LIMITED NUMBER OF LEVELS

• IMPORTANT VARIABLES HAVE MUCH GREATER EFFECTS THAN ALL THE UNIMPORTANT VARIABLES COMBINED

• THE ERROR OF EXPERIMENT IS SMALL

• NO SIGNIFICANT INTERACTIONS



MOTIVATING EXAMPLE

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COMMAND AND CONTROL IN MILITARY CONFLICT

Red Forces	Blue Forces
Red agents in cell	Blue agents in cell
box center x	box center x
box center y	box center y
box size x	box size x
box size y	box size y
goal x	goal x
goal y	goal y
probability hit	probability hit
speed	speed
sensor/shoot range	sensor/shoot range
charge ratio	charge ratio
retrograde ratio	retrograde ratio
maximum hits	maximum hits

APPROACH

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DETERMINE A METHODOLOGY AND ASSOCIATED THEORY TO EFFICIENTLY SEARCH ACROSS THE BREADTH OF FACTORS TO IDENTIFY NOT ONLY MAIN EFFECTS, BUT ALSO CRITICAL SECOND-ORDER (AND PERHAPS THIRD-ORDER) INTERACTIONS.

HYPOTHESIS: AN ADAPTIVE SEQUENTIAL DESIGN COMBINING TRADITIONAL FULL AND FRACTIONAL FACTORIAL DESIGNS, LATIN SUPERCUBE, AND SUPERSATURATED DESIGNS TOGETHER WITH RANDOM PERTURBATIONS, GROUP SCREENING, AND EXPERT JUDGMENT IS *EFFICIENT* IN IDENTIFYING CRITICAL EFFECTS AND SECOND-ORDER INTERACTIONS.

USE COMMAND AND CONTROL AGENT-BASED SIMULATION TO VERIFY METHODOLOGY AND THEORY

MANY MODELS CANNOT DO THIS DUE TO SCRIPTING.

FURTHER DETAILS (I)

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GENERAL DIRECTION: IN COMPARISON TO FRACTIONAL FACTORIAL DESIGNS, THERE WILL BE FEWER RUNS (ADVANTAGE). IN ADDITION, THE LIMITATIONS OF MAIN EFFECTS ONLY FACTOR SCREENING WILL BE ELIMINATED IN AN ATTEMPT TO IDENTIFY INTERACTIONS AS WELL (ADVANTAGE).

OF COURSE WHETHER THE PROPOSED METHODOLOGY IS SUCCESSFUL OR NOT IS THE NATURE OF THE DISSERTATION. THE FOLLOWING SLIDE ILLUSTRATES THE INITIAL PROPOSED METHODOLOGY. A THOROUGH LITERATURE REVIEW WILL PRECEDE THIS EXPERIMENTATION. THE LITERATURE REVIEW WILL COVER THOSE SOURCES LISTED IN THE ATTACHED PAPER AS WELL AS BAYESIAN THEORY, SEQUENTIAL METHODS, AND PREDICTIVE INFERENCE. A PARTIAL LITERATURE REVIEW HAS ALREADY BEEN COMPLETED.

FURTHER DETAILS (II)

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I) Identify all variables (input) of the model - regardless if you can influence the variable of not. This relates to Professor Sanchez's robustness.

II) Establish the measure or measures of effectiveness (output). We must consider a weighting criteria if there are multiple MOE's since the MOE's can be in contrast to one another. Sensitivity analysis may be used (robustness).

III) Using expert judgment/experience, group the variables into one of 3 categories - likely to influence MOE(s), possible influencing MOE(s), and unlikely to influence MOE(s).

IV) Assign a prior probability to those variables in the likely to influence or possible influencing category - of course the appropriate conjugate prior assigned could be difficult. Further research - what happens if we misspecify our prior distribution - what is the worst case for the number of additional runs required for correct identification of the important effects / interactions?

V) Once satisfied with the important factors and interactions, conduct perturbation analysis - there would be seven perturbations. One with just the likely to influence, one with possible, one with none, one with influence and possible, one with influence and none, one with possible and none, and then with all of them. Assign some random (perhaps normal error) for the perturbations.

CONCLUSIONS

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• RESEARCH IN SUPPORT OF MARINE CORPS COMBAT DEVELOPMENT COMMAND (MCCDC) AND PROJECT ALBERT.

• PROFESSORS TOM LUCAS AND SUSAN SANCHEZ ARE LEAD RESEARCHERS AT NPS.

• DISSERTATION WILL CONTRIBUTE PRIMARILY TO EXPERIMENTAL DESIGN IN COMPLEX MODELS AND SECONDARILY TO COMMAND AND CONTROL.

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