WHAT'S THE PROBLEM?

Selecting the Right Statistical Tool for the Job in a Resource-Constrained Environment

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OVERVIEW

- The problem
- Statistical techniques
- Comparison of statistical techniques
- Some guidelines
- Summary

THE PROBLEM

- "I need to use DOE"
- DOE is only one tool in the toolbox
- Very few guidelines on appropriate statistical techniques, especially for DT&E
- Current DT&E statistical approaches not widely recognized, for example:
  - Parameter estimation using maximum likelihood estimation approaches
  - Instrumentation error estimation
  - Navigation system error computations

STATISTICAL TECHNIQUES & TOOLS

- **Some techniques:**
  - **Frequentist – e.g., t-test, ANOVA**
  - **Bayesian – incorporate prior information**
  - **Information theoretic – multiple hypotheses, based on likelihood approaches**
- **Some tools:**
  - **DOE**
  - **Monte Carlo simulation**

Frequentist techniques are popular primarily because the other approaches were difficult to implement until the past two decades due to computational limitations.

COMPARISON OF STATISTICAL TECHNIQUES

	Frequentist	Bayesian	Information Theoretic
Basic premise	Reject null hypothesis	Degree of belief	Strength of evidence
Application	Easy	Difficult	Moderate
Interpretation	Easy	Easy	Easy
Explanation	Difficult	Easy	Easy
Assumptions	Many implicit	Priors	Explicit
Hypotheses/Models	One	N/A	Multiple
Use of Prior Data	No	Yes	Maybe
Engineering judgment	None	Lots	Lots

COMPARISON OF STATISTICAL TOOLS: DOE

- Very useful for "black-box" tests where no model exists due to:
  - No or little prior knowledge
  - System complexity
- Requires assumptions:
  - Known or estimated variance
  - Independent data
  - Test articles are randomly selected and treatments are randomly assigned

Assumptions aren't the problem; the problem is that people do not understand the impact of the assumptions on the test design and analysis.

COMPARISON OF STATISTICAL TOOLS: MONTE CARLO SIMULATION

- Provide a more general method for test planning and data analysis
- Assumptions are explicit, because they must be modeled
- Can handle any type of data and easily incorporates a physics-based model
- Simulate possible populations both pre- and post-test
- Don't have to be concerned with α, β, δ, etc.
- Have to write your own code/script

SOME GUIDELINES

- What do you know already?
- What is the test purpose?
- What kind of data are available?
- What assumptions are you making?
- What kind of analysis techniques do you have available?
- How much time do you have?

WHAT DO YOU KNOW ALREADY?

- If you know a lot, you may not even need statistics
- If you know something, you can:
  - Validate and update models with Bayesian or likelihood approaches
  - Choose among competing models or weight models with information theoretic approaches
- If you know nothing or very little, you can:
  - Develop empirical models using DOE, Bayesian or information theoretic approaches

WHAT IS THE TEST PURPOSE?

- Spec compliance – hypothesis tests must be very carefully constructed
- Update or spot-check existing model
- Build empirical model
- Explore operational space
- Demonstration

WHAT KIND OF DATA ARE AVAILABLE?

- Accuracy and precision of instrumentation
- Type of data and characteristics
  - Continuous
  - Survey
  - Censored
  - Time history
  - Data rate
  - etc

WHAT ASSUMPTIONS ARE YOU MAKING?

- Make sure you understand your assumptions and the impact on your conclusions if not valid
- Be explicit, even if assumptions are implicit (e.g., if using a null hypothesis significance test)

WHAT KIND OF ANALYSIS TECHNIQUE DO YOU HAVE AVAILABLE AND HOW MUCH TIME DO YOU HAVE?

- Limited computational power or time available may drive to a frequentist or likelihood approach
- Bayesian techniques require specific computer software for analysis
- Advanced techniques require specialized knowledge to ensure applied correctly
  - Access to statistical experts is crucial

SOME GUIDELINES

- Match the technique you are using to the question you are answering/the purpose of the test and your prior understanding of the problem
- State all assumptions explicitly
- If time, use simulation to determine how well different techniques work based on different assumptions or different postulated results

OTHER GUIDELINES DEPENDING ON TEST PURPOSE AND DATA

TEST PURPOSE	DATA		
	Normal (Gaussian)	Rank, Score, Non-Normal	Binomial (Two outcomes)
Describe one group	Mean, SD	Median, Interquartile range	Proportion
Compare one group to a constant	One-sample t-test	Wilcoxon's Signed-Rank test, Exact Permutation test, Sign test	Binomial or Chi-square
Compare two unpaired groups	Unpaired t-test	Exact (Permutation), Rank-Sum (Wilcoxon or Mann-Whitney), Welch's t-test	Fisher's Exact test, Chi-square (approximate)
Compare two paired groups	Paired t-test	Wilcoxon's Signed-Rank test, Exact Permutation test, Sign test	McNemar's test
Compare 3+ unmatched groups	1-way ANOVA	Kruskal-Wallis	Chi-square
Compare 3+ matched groups	Repeated measures ANOVA	Friedman test	Cochrane's Q
Quantify association between two variables	Pearson correlation	Spearman correlation	Contingency coefficients
Predict a value from one other variable	Simple linear/non-linear regression	Nonparametric regression	Simple logistic regression
Predict a value from several other variables	Multiple linear/non-linear regression		Multiple logistic regression

Taken from H. Motulsky, "Intuitive Biostatistics," © OUP, 1st ed. 1995.

SUMMARY

- Lots of tools in the toolbox – understand them!
- Don’t use a hammer when you need a wrench
- Don’t try to use statistics when you don’t need to
- Still lots of room for engineering judgment