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A 5 Day Course on

Reliability Demonstration and Assessment with Info-Gap Theory

Course Rationale

Reliability demonstration and assessment is the application of measurement techniques and statistical analysis for determination of the degree to which a system satisfies specified performance requirements. Statistical tests depend on various assumptions—normality, independence, randomness, etc.—which are not always valid. Furthermore, sometimes measurements are made on sub-systems or proto-types from which inferences must be drawn about other systems. In all these situations we face info-gaps: disparities between what *is known* and what *needs to be known* in order to draw sound conclusions. In this course we study the application of info-gap theory to the problem of statistical inference when assumptions are violated or essential data or models are missing. That is, we study tools which augment standard statistical analysis.

Course Structure

This course has three components. *Lectures* present new material and *exercises* allow the participants to master this material. Most of the first three days are devoted to lectures and exercises. The last two days are devoted to *mini-projects* which are formulated and implemented by the participants, in small groups. This facilitates the thorough internalization of the concepts and methods learned. The instructor assists the groups in developing their mini-projects.

The Instructor

Professor Yakov Ben-Haim is the "Father" of Info-Gap Decision Theory. Info-gap theory is a quantitative methodology for modelling and managing severe uncertainty that is applied in engineering analysis and design, reliability analysis, project management, monetary policy, homeland security, biological conservation and medicine. Prof. Ben-Haim has lectured at universities, medical and technological research institutions and central banks throughout the world and has been a visiting scholar in 10 different countries. He has published 4 books and more than 70 articles. He holds the Yitzhak Moda'i Chair in Technology and Economics at the Technion—Israel Institute of Technology. Prof. Ben-Haim has a B.A. from Beloit College and both an M.Sc. and a Ph.D. from the University of California, Berkeley.

The Participants

This course is intended for reliability and systems engineers with practical experience and sound mathematical ability at the university level. Participants will need access to personal computers for implementation of the mini-projects.

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Overview of the 5 days

Day 1: *Lectures and exercises.* Modelling and managing uncertain systems, probabilistic reliability with info-gap uncertainty.

Day 2: *Lectures and exercises.* Info-gap analysis of uncertain dynamical systems.

Day 3: *Lectures, exercises and mini-projects.*
- Moment assay, spatial assay, Poisson and info-gap uncertainty, forecasting.
- Formulation of working groups for mini-projects.

Day 4: *Mini-projects.* Mathematical formulation and implementation.

Day 5: *Mini-projects.* Prepare reports. Group presentations.

Following is a detailed schedule of each day of the course. The footnotes identify source material. Each sesson runs for 50 minutes, followed by a ten minute break.

Day 1

Lecture: *Project management with uncertain task times.* We wish to allocate resources among tasks whose duration is highly uncertain.[1]
Lecture: *Estimating an uncertain pdf.* We measure a test system which differs from the actual system. How to estimate the pdf?[2]
Exercise: *Estimating spring stiffness.*[3]

Lunch

Lecture: *Limitations of probability.* Probability is a powerful tool, but not applicable in all situations. We illustrate this and discuss several paradoxes of probability.[4]
Lecture: *Probabilistic reliability with info-gap uncertainty.* What to do when the tails of the probability distribution are uncertain? Combining info-gap robustness with probabilistic reliability.[5]
Exercise: *Probabilistic reliability with info-gap uncertainty.*[6]

Day 2

Lecture: *Design of vibrating system with uncertain load.* We wish to choose a design concept for stabilizing a vibrating system subject to load uncertainty. Should we use stiffness, or damping, or a combination?[7]
Lecture: *Design of vibrating system with uncertain load, continued.*
Exercise: *Dynamic stability of a platform.*[8]

Lunch.

Lecture: *Ellipsoidal models of uncertainty.* Historical data is often recorded as mean vector and covariance matrix. However, we don't know the future pdf. This information can be used in an ellipsoid-bound info-gap model of uncertainty.[9]
Lecture: *Linear system with quadratic info-gaps.* We study a portfolio investment paradigm.[10]
Exercise: *Static deflection of a cantilever.*[11]

[1](1) Lecture Notes on Info-Gaps in Project Management Knowledge Areas, section 4. (2) Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., 2006, (henceforth *"IGDT"*), section 3.2.6.

[2](1) Lecture Notes on Info-Gap Estimation and Forecasting, section 2. (2) *IGDT*, section 3.2.13.

[3]Problem set on Robustness and Opportuneness, #38.

[4](1) Lecture Notes on Info-Gap Uncertainty, sections 1 and 2. (2) Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., 2006, (henceforth *"IGDT"*), sections 2.2 and 2.3.

[5](1) Lecture Notes on Probabilistic Failure Models, section 13. (2) *IGDT*, section 10.2.

[6]Problem Set on Hybrid Uncertainties, #2.

[7](1) Lecture Notes on Robustness and Opportuneness, section 6. (2) *IGDT*, section 3.2.1.

[8]Problem set on Robustness and Opportuneness, #9.

[9](1) Lecture Notes on Robustness and Opportuneness, section 2.3. (2) Problem Set on Info-Gap Uncertainty, #5 will be discussed.

[10](1) Lecture Notes on Robustness and Opportuneness, section 12. (2) *IGDT*, section 3.2.7.

[11]Problem on Robustness and Opportuneness, #4.

Day 3

Lecture: *Moment assay.* Suppose we want to determine the total quantity, or average location of a spatially distributed entity (e.g. crack, pollutant, irregular thin film, etc.) whose spatial distribution is unknown. In other words, we seek a zeroth or first moment of the distribution. Info-gap theory is a tool for designing and interpreting the measurement.[12]
Exercise: *Spatial assay.*[13]
Lecture: *Info-gap robustness of a Poisson process.* Many discrete random processes, such as spatial distribution of flaws, temporal distribution of failures, and queueing systems, can be described as Poisson processes. However, the statistical model depends on the assumptions of independence of events and constant mean rate. We use info-gap theory to analyze such systems when these assumptions are violated.[14]

Lunch.

Exercise: *Discrete random processes with info-gaps.*[15]
Lecture: *Forecasting.* We sometimes need to forecast the value of a variable, based on a fragmentary and erroneous model. Info-gap theory can help formulate a reliable forecasting algorithm.[16]
Mini-projects. Guidelines for working groups. Brainstorming on decision problems. Break into working groups. Verbally formulate decision, uncertainty models, system models, and performance requirements.

Day 4

Morning milestones: Mathematically formulate uncertainty models, system models, performance requirements. Initiate calculation of robustness functions.

Lunch.

Early afternoon: 10-minute presentation by each group.

Afternoon milestones: Progress in robustness curve calculation.

Day 5

Morning milestones: Project report written.

Lunch.

Afternoon milestones: Presentations.

[12] (1) Lecture Notes on Robustness and Opportuneness, section 14.1. (2) *IGDT*, section 3.2.10.
[13] Problem Set on Robustness and Opportuneness, #8.
[14] (1) Lecture Notes on Hybrid Uncertainties, section 1. See also sections 2.3–2.5. (2) *IGDT*, sections 10.1 and 10.4.
[15] Problem Set on Hybrid Uncertainties, #1.
[16] (1) Lecture Notes on Info-Gap Estimation and Forecasting, section 3. (2) *IGDT*, section 3.2.13.