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ELEC 638 — A graduate course on:
Info-Gap Theory and its Applications

Electrical and Computer Engineering Dept.
Rice University
October–November 2010

Syllabus. Strategic decisions under uncertainty in analysis, design and certification of complex systems. Assessment and control of reliability and risk. Project management. Decision paradigms for information-gap uncertainty. Realizability with limited information. Balancing trade-offs between robustness, performance and opportuneness. Evolution of preferences through analysis of uncertainty. Value judgments. Decisions with multiple criteria. Learning and the value of information. Decisions with hybrid uncertainties.

Audience. Persons involved in strategic decisions in a complex environment with severe uncertainty: engineers developing new and complex technologies, engineers in project management roles, systems engineers, systems analysts, project managers.

Related areas. Information theory, game theory, operations research, interactive decision making, conflict resolution, project management, analysis and design of systems.

Prerequisites. This course is based on concepts and methods drawn from the analysis of systems under uncertainty. Basic tools from linear algebra, differential equations, probability theory are employed.

Course Structure. This course has three components. *Lectures* present new material and *exercises* allow the participants to master this material. In the latter half of the course participants will be encouraged to formulate *mini-projects*, either individually or in small groups. This facilitates the thorough internalization of the concepts and methods learned, their integration with other methods familiar to the participants, and their application to problems of interest.

Time and date of lectures. 14 two-hour lectures, 9–11am, Wednesdays and Fridays. Starting 6 October and finishing 19 November.

Location. Abercrombie B209.

Credit. The course will be 3 credits.

Grading.

Homework. (once a week): Required. 1 point for each plausible homework set, up to a maximum of 5 points. Homework contributes 5% of the final grade.

Project. Required. Each student individually defines a mini-project and writes a report of no more than 10 pages developing the info-gap analysis of the problem. Students are encouraged to consult me during formulation and development of their mini-projects. The grade is based on technical correctness, understanding, depth, scope, originality and quality of presentation. The mini-project contributes 60% of the grade.

Final Exam. Required. After the last lecture we will have a written take-home exam which contributes 35% of the grade. Open material (no friends!).

Outline of Lectures

1. (Lecture 1) **Severe uncertainty.** Paradoxes of probability. Intuitive and quantitative discussion of types of uncertainty: information gaps, linguistic and probabilistic uncertainty. Hybrid uncertainty models.¹
2. (Lecture 2) **Queueing theory.** Uncertain arrival rates. Design of server size.²
3. (Lecture 3) **Resource allocation and investment-like problems.** Trade-off between performance and robustness to uncertainty. Opportunity from uncertainty.³
4. (Lecture 4) **Probabilistic reliability with info-gap uncertainty.**⁴ Discrete system with 2 sub-units: reliability, redundancy, uncertain correlations.⁵ Origin of fat-tailed probability distributions. Value at risk. Quantile uncertainty.⁶ Quantile risk.⁷
5. (Lecture 5) **Accelerated lifetime testing.** Design an accelerated lifetime test when the relation between stress-augmentation and lifetime is uncertain.⁸
6. (Lectures 6, 7) **Info-Gap Statistics.**⁹ Embed a statistical test in an info-gap robustness analysis. Distributional uncertainty. Statistical test of the mean with distributional uncertainty.¹⁰ Test of false nulls with uncertain sampling distribution.¹¹
7. (Lectures 8, 9) **Estimation and modelling.** Updating a system model from info-gap-uncertain data. Tichonov regularization with info-gap uncertainty in the model structure.¹²
8. (Lecture 10) **Value judgments.** How safe is safe enough? How much reliability is needed? How good is our decision? Qualitative calibration of quantitative trade-offs. Analogical reasoning. Calibration by severity of consequences; by prior information.¹³
9. (Lecture 11) **Value of information.** Assessing the value of information with respect to system goals, and exploiting this evaluation to optimize further information-gathering. Demand value of information in systems with generic (not necessarily monetary) reward.¹⁴
10. (Lectures 12, 13) **Robust-satisficing behavior.** Analysis of Ellsberg and Allais “paradoxes” of behavior under uncertainty. Examination of info-gap robust-satisficing resolutions.¹⁵

¹o Yakov Ben-Haim, *Info-Gap Decision Theory*, 2nd ed. (Henceforth “*IGDT*”), sections 2.2, 2.5.

o Y. Ben-Haim, 2004, Uncertainty, probability and information-gaps, *Reliab. Eng. & System Safety*, 85: 249–266.

o Decisions, Decisions Info-Gap Theory and Severe Uncertainty, \lectures\talks\lib\rice2010Lec01.pdf.

o Lecture Notes on Info-Gap Uncertainty (\risk\lectures\igunc.pdf), pp.2–11.

o Homework: Lewis Carroll on transcendental probability, Problem Set on Info-Gap Uncertainty, #8.

²o *IGDT*, 2nd ed., section 3.2.7.

o Lecture Notes on Hybrid Uncertainties (\lectures\risk\lectures\hybunc.pdf, sections 2.3–2.5)

³Lecture Notes on Robustness and Opportuneness (\risk\lectures\ro.pdf) section 12.

⁴durham2010Lec02.pdf

⁵Yakov Ben-Haim, 2010, *Info-Gap Economics: An Operational Introduction*, (henceforth “*IGE*”), Palgrave-MacMillan, section 4.1.

⁶(1) *IGE*, sec. 4.2. (2) Lecture Notes on Probabilistic Failure Models (pfm.tex), sec. 13. (3) *IGDT*, section 10.2.

⁷Lecture Notes on Probabilistic Failure Models (pfm.tex), section 13.

⁸Lecture Notes on Acceptance Testing (acctes.tex), section 10. Problem Set on Acceptance Tests (hwacc.tex), #11.

⁹durham2010Lec03.pdf

¹⁰Tania Mirer and Yakov Ben-Haim, 2010, Reliability Assessment of Explosive Material Based on Penalty Tests: An Info-Gap Approach, Proceedings of the Institution of Mechanical Engineers, Part O, *Journal of Risk and Reliability*, to appear.

¹¹(1) Yakov Ben-Haim, 2010, Interpreting Null Results from Measurements with Uncertain Correlations: An Info-Gap Approach, *Risk Analysis*, to appear. (2) L.J. Moffitt and Yakov Ben-Haim, 2010, Robustness Analysis of Expert Dispute About Incubation Time, working paper.

¹²Lecture Notes on Info-Gap Estimation and Forecasting, estim01.tex.

¹³o Yakov Ben-Haim, *Info-Gap Decision Theory*, 2nd ed., chapter 4.

o Lecture Notes on Value Judgements (\risk\lectures\vjud.pdf) various sections.

¹⁴o Yakov Ben-Haim, *Info-Gap Decision Theory*, 2nd ed., chapter 7.

¹⁵o Yakov Ben-Haim, *Info-Gap Decision Theory*, 2nd ed., chapter 11.

o Lecture Notes on Robust-Satisficing Behavior (\risk\lectures\rsb01.pdf) various sections.

11. (Lecture 14) **Learning under uncertainty.** We use info-gap theory to study the design and evaluation of learning strategies.¹⁶

Books

The main text is:

Yakov Ben-Haim, 2006, *Info-Gap Decision Theory: Decisions Under Severe Uncertainty*, 2nd edition, Academic Press.

Supplementary material includes:

1. Yakov Ben-Haim, 2010, *Info-Gap Economics: An Operational Introduction*, Palgrave.
2. Yakov Ben-Haim, 2005, Info-gap Decision Theory For Engineering Design. Or: Why ‘Good’ is Preferable to ‘Best’, appearing as chapter 11 in *Engineering Design Reliability Handbook*, Edited by Efstratios Nikolaidis, Dan M.Ghiocel and Surendra Singhal, CRC Press, Boca Raton.
3. Yakov Ben-Haim, 2009, Info-gap forecasting and the advantage of sub-optimal models, *European Journal of Operational Research*, 197: 203–213.
4. David E. Bell, Howard Raiffa and Amos Tversky, eds., 1988, *Decision Making: Descriptive, Normative, and Prescriptive Interactions*, Cambridge University Press.
5. Yakov Ben-Haim, 1996, *Robust Reliability in the Mechanical Sciences*, Springer-Verlag, Berlin.
6. Yacov Y. Haimes, 1998, *Risk Modeling, Assessment, and Management*, John Wiley.
7. Ralph Keeney, 1992, *Value Focussed Thinking*, Harvard University Press.
8. Ralph L. Keeney and Howard Raiffa, 1993, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, Cambridge University Press.
9. M. Granger Morgan and Max Henrion, 1990, *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. With a chapter by Mitchell Small. Cambridge University Press.
10. <http://info-gap.com>

¹⁶o Yakov Ben-Haim, *Info-Gap Decision Theory*, 2nd ed., chapters 7 and 8.

o Lecture Notes on Info-Gap Learning ([\risk\lectures\lrn.pdf](#)) various sections.