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A Four-Day Workshop on

Info-Gap Theory and Its Applications in Design and Strategic Planning

Sandia National Laboratories, Albuquerque, NM
15–18 August 2011

Course Rationale

Decisions under uncertainty arise in many disciplines, including engineering, economics, public policy, medicine, biological conservation, homeland security and so on. In these disciplines one uses data and models to formulate and evaluate designs and plans.

Info-gap theory is a method for analysis, planning, decision and design under uncertainty. The future may differ from the past, so our models may err in ways we cannot know. Our data may lack evidence about surprises: catastrophes or windfalls. Our scientific and technical understanding may be incomplete. These are info-gaps: incomplete understanding of the system being managed. Info-gap theory provides decision-support tools for modelling and managing severe uncertainty. Info-gap theory has been applied by scholars around the world in engineering, biological conservation, financial and monetary economics, project management, medicine and homeland security, and more.

This workshop is devoted to learning the methodology of info-gap analysis and its integration with other decision tools.

Course Structure

This course has three components. *Lectures* present new material and *exercises* allow the participants to master this material. The first two 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, their integration with other methods familiar to the participants, and their application to problems of interest.

Selected Sources

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

2. Yakov Ben-Haim, 2010, *Info-Gap Economics: An Operational Introduction,* Palgrave.

3. 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.

4. Yakov Ben-Haim, 2009, Info-gap forecasting and the advantage of sub-optimal models, *European Journal of Operational Research,* 197: 203–213.

5. Yakov Ben-Haim, Interpreting null results from measurements with uncertain correlations: An info-gap approach, *Risk Analysis,* vol.31 (1), pp.78–85.

6. Tania 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,* vol. 224(4), pp.346–355.

7. Yakov Ben-Haim, Clifford C. Dacso, Jonathon Carrasco and Nithin Rajan, 2009, Heterogeneous Uncertainties in Cholesterol Management, *International Journal of Approximate Reasoning,* 50: 1046–1065.

8. Lior Davidovitch and Yakov Ben-Haim, 2008, Is your profiling strategy robust? To appear in *Law, Probability and Risk.*

9. Lior Davidovitch and Yakov Ben-Haim, 2010, Robust satisficing voting: Why are uncertain voters biased towards sincerity? *Public Choice,* vol.145, Issue 1, pp.265–280.

10. Barry Schwartz, Yakov Ben-Haim, and Cliff Dacso, What Makes a Good Decision? Robust Satisficing as a Normative Standard of Rational Behaviour, *The Journal for the Theory of Social Behaviour,* to appear.

11. http://info-gap.com

Brief Outline

Day 1 Monday 15 August 2011
    MORNING
        09:30–10:20 *Lecture 1. Info-Gap Theory: Overview and Examples.*
        10:30–11:20 *Lecture 2. Probabilistic reliability with info-gap uncertainty.*
        11:20–11:40 Coffee break.
        11:40–12:30 *Lecture 3. Info-Gap Statistics.*
    LUNCH 12:30–14:00
    AFTERNOON
        14:00–14:50 *Exercises:*
            ○ Standard: *Trigger mechanism.*
            ○ Standard: *Managerial attention.*
            ○ Challenge: *Static deflection of a cantilever.*
        15:00–15:50 *Exercise. Choosing between two discrete lotteries.*
        15:50–16:10 Coffee break.
        16:10–17:00 *Exercise.*
            ○ Standard: *Investment for bio-diversity.*
            ○ Standard: *Search and evasion.*
            ○ Challenge: *Estimate spring stiffness with model uncertainty.*

Day 2 Tuesday 16 August 2011
    MORNING
        09:30–10:20 *Lecture 4. Optimizer's Curse: An Info-Gap Response.*
        10:30–11:20 *Lecture 5. Strategic interactions.*
        11:20–11:40 Coffee break.
        11:40–12:30 *Lecture 6. Forecasting.*
    LUNCH 12:30–14:00
    AFTERNOON
        14:00–14:50 *Exercise: Accelerated lifetime testing.*
        15:00–15:50 *Exercise: Spatial monitoring.*
        15:50–16:10 Coffee break.
        16:10–17:00 *Exercise: Estimation.*
            ○ Standard: *Non-linear force-deflection relation.*
            ○ Standard: *Adversarial behavior.*
            ○ Challenge: *Extrapolating an S-N curve.*

Day 3 Wednesday 17 August 2011
    MORNING
        09:30–12:30 *Brain-storm and initiate mini-projects.*
    LUNCH 12:30–14:00
    AFTERNOON
        14:00–17:00 *Guided independent work on mini-projects.*

Day 4 Thursday 18 August 2011
    MORNING
        09:30–12:00 *Guided independent work on mini-projects.*
        12:00–12:30 *Preliminary reports on mini-projects.*
    LUNCH 12:30–14:00
    AFTERNOON
        14:00–17:00 *Guided independent work on mini-projects.*

Detailed Outline

Day 1 Monday 15 August 2011

   Morning

      09:30–10:20 *Lecture 1. Info-Gap Theory: Overview and Examples.*[1]

- Examples of severe info-gaps.
- Principle of indifference.[2] Probability is powerful but not applicable in all situations. We illustrate this and discuss several paradoxes of probability.
- Expected utility with uncertain probabilities, or: Save the Sumatran rhinoceros.[3]
- Estimating an uncertain pdf.[4]

      10:30–11:20 *Lecture 2. Probabilistic reliability with info-gap uncertainty.*[5]

- Discrete system with 2 sub-units: reliability, redundancy, uncertain correlations.[6]
- Origin of fat tails.
- Value at risk. Quantile uncertainty.[7]
- Quantile risk.[8]

      11:20–11:40 Coffee break.

      11:40–12:30 *Lecture 3. Info-Gap Statistics.*[9]

- Embedding 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]

   Lunch 12:30–14:00

   Afternoon

      14:00–14:50 *Exercises:*

- Standard: *Trigger mechanism.*[12]
- Standard: *Managerial attention.*[13]
- Challenge: *Static deflection of a cantilever.*[14]

      15:00–15:50 *Exercise. Choosing between two discrete lotteries.*[15]

      15:50–16:10 Coffee break.

      16:10–17:00 *Exercise.*

- Standard: *Investment for bio-diversity.*[16]
- Standard: *Search and evasion.*[17]
- Challenge: *Estimate spring stiffness with model uncertainty.*[18]

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[1] **lanl2011ws-Lec01.pdf**

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

[3] Lecture Notes on Conservation Management, or: Robustness, Expected Utility and the Sumatran Rhinoceros (rhino.tex).

[4] (1) Lecture Notes on Info-Gap Estimation and Forecasting (estim.tex), section 4, (2) *IGDT,* section 3.2.13.

[5] **lanl2011ws-Lec02.pdf**

[6] Yakov Ben-Haim, 2010, *Info-Gap Economics: An Operational Introduction,* (henceforth *"IGE"*), Palgrave-MacMillan, section 4.1.

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

[8] Lecture Notes on Probabilistic Failure Models (pfm.tex), section 13.

[9] **lanl2011ws-Lec03.pdf**

[10] Tanya Mirer and Yakov Ben-Haim, 2010, Reliability Assessment of Explosive Material Based on Penalty Tests: An Info-Gap Approach, working paper.

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

[12] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex), #41.

[13] Problem Set on Info-Gap Risks in Project Management (p-mgt-hw01.tex), #18(a).

[14] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex), #4.

[15] Problem Set on Hybrid Uncertainties (pshybunc01.tex) #10.

[16] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex) #35.

[17] .

[18] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex) #38.

Day 2 Tuesday 16 August 2011

 Morning

  09:30–10:20 *Lecture 4. Optimizer's Curse: An Info-Gap Response.*[19]

   ○ Why best-model optimization is not a good bet if the best model is highly uncertain.[20]

  10:30–11:20 *Lecture 5. Strategic interactions.*[21]

   ○ We study planning and response in strategic interactions with an uncertain opponent.

  11:20–11:40 Coffee break.

  11:40–12:30 *Lecture 6. Estimation and Forecasting.*[22]

   ○ Use regression to predict with preliminary data from an unstable process.[23]

 Lunch 12:30–14:00

 Afternoon

  14:00–14:50 *Exercise: Accelerated lifetime testing.*

   ○ Background.[24]

   ○ Exercise.[25]

  15:00–15:50 *Exercise: Spatial monitoring.*[26]

  15:50–16:10 Coffee break.

  16:10–17:00 *Exercise: Estimation.*

   ○ Standard: *Non-linear force-deflection relation.*[27]

   ○ Standard: *Adversarial behavior.*[28]

   ○ Challenge: *Extrapolating an S-N curve.*[29]

Day 3 Wednesday 17 August 2011

 Morning

  09:30–10:30 *Brainstorming on mini-projects.*

  10:30–12:30 *Guided independent work on mini-projects.*

 Lunch 12:30–14:00

 Afternoon

  14:00–17:00 *Guided independent work on mini-projects.*

Day 4 Thursday 18 August 2011

 Morning

  09:30–12:00 *Guided independent work on mini-projects.*

  12:00–12:30 *Preliminary reports on mini-projects.*

 Lunch 12:30–14:00

  14:00–17:00 *Guided independent work on mini-projects.*

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[19] **lanl2011ws-Lec04.pdf**

[20] (1) Lecture Notes on the Optimizer's Curse (optimizers-curse03.tex). (2) *IGDT,* section 11.4.

[21]

 Supporting material:

(1) *IGDT,* section 3.2.9.

(2) *IGE,* section 3.4.

(3) Lecture Notes on Robustness and Opportuneness (\risk\lectures\ro.tex), section 13.

[22] **lanl2011ws-Lec06.pdf**.

[23] *IGE,* sections 6.1, 6.2.

[24] Lecture Notes on Acceptance Testing (acctes.tex), section 10.

[25] Problem Set on Acceptance Tests (hwacc.tex), #11.

[26] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex) #33.

[27] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex) #31.

[28] .

[29] Problem Set on Robustness and Opportuneness (ps2_rk-h01.tex) #47.