Dr. Yakov Ben-Haim
Professor
Yitzhak Moda'i Chair in
Technology and Economics

Technion
Israel Institute of Technology
Faculty of Mechanical Engineering
Haifa 32000 Israel

http://info-gap.com Blog: http://decisions-and-info-gaps.blogspot.com http://www.technion.ac.il/yakov
Tel: +972-4-829-3262, +972-50-750-1402 Fax: +972-4-829-5711
yakov@technion.ac.il

A Four-Day Workshop on

Info-Gap Theory and Its Applications in Engineering Analysis and Design Under Uncertainty

NASA–Langley Research Center
Hampton, Virginia
10–13 September 2012

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.

The Participants

Engineers involved in analysis and design under uncertainty.

[0] \lectures\WShops+ShrtCrs\NASA-Langley2012\outline03nasa2012.tex 27.8.2012

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,* 10: 59–76.
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, 2011, What Makes a Good Decision? Robust Satisficing as a Normative Standard of Rational Behaviour, *The Journal for the Theory of Social Behaviour,* 41(2): 209–227..
11. Yoshihiro Kanno and Yakov Ben-Haim, 2011, Redundancy and Robustness, Or, When is Redundancy Redundant? ASCE *Journal of Structural Engineering,* 137(9): 935–945.
12. Yakov Ben-Haim and Francois Hemez, 2012, Robustness, Fidelity and Prediction-Looseness of Models, *Proceedings of the Royal Society,* A, 468: 227–244.
13. http://info-gap.com

Brief Outline

Day 1 Monday 10 September 2012

Morning

09:00–9:50 *Lecture 1. Info-Gap Theory: Overview and Examples.*
10:00–10:50 *Lecture 2. Probabilistic Reliability with Info-Gap Uncertainty.*
10:50–11:10 Coffee break.
11:10–12:00 *Lecture 3 Vibration Suppression with Uncertain Load.*

Lunch 12:00–13:00

Afternoon

13:00–13:50 *Exercise. Trigger mechanism.*
14:00–14:50 *Exercise. Adaptive force balancing.*
14:50–15:10 Coffee break.
15:10–16:00 *Exercise. Search and evasion.*

Day 2 Tuesday 11 September 2012

Morning

09:00–9:50 *Lecture 4. Optimizer's Curse: An Info-Gap Response.*
10:00–10:50 *Lecture 5. Estimation and Forecasting.*
10:50–11:10 Coffee break.
11:10–12:00 *Lecture 6. Info-Gap Statistics.*

Lunch 12:00–13:00

Afternoon

13:00–13:50 *Exercise: Braking system.*
14:00–14:50 *Exercise: Choosing between two discrete lotteries.*
14:50–15:10 Coffee break.
15:10–16:00 *Exercise: Accelerated lifetime testing.*

Day 3 Wednesday 12 September 2012

Morning

09:00–12:00 *Brain-storm and initiate mini-projects.*

Lunch 12:00–13:00

Afternoon

13:00–14:00 Public lecture: *Model-Based Planning for an Uncertain Future: An Info-Gap Approach.*
14:00–17:00 *Guided independent work on mini-projects.*

Day 4 Thursday 13 September 2012

Morning

09:00–11:00 *Guided independent work on mini-projects.*
11:00–12:00 *Preliminary reports on mini-projects.*

Lunch 12:00–13:00

Afternoon

13:00–16:00 *Guided independent work on mini-projects.*

Detailed Outline

Day 1 Monday 10 September 2012

MORNING

09:00–9:50 *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.
- Applications of info-gap theory.

10:00–10:50 *Lecture 2. Probabilistic Reliability with Info-Gap Uncertainty.*[3]

- Discrete system with 2 sub-units: reliability, redundancy, uncertain correlations.[4]
- Origin of fat tails.
- Value at risk. Quantile uncertainty.[5]
- Quantile risk.[6]

10:50–11:10 Coffee break.

11:10–12:00 *Lecture 3. Vibration Suppression with Uncertain Load.*[7]

- We consider the choice between stiffness and damping in designing a vibrating cantilever subject to uncertain impact loads.

10:50–11:10 Coffee break.

LUNCH 12:00–13:00

AFTERNOON

13:00–13:50 *Exercise. Trigger mechanism.*[8]

14:00–14:50 *Exercise. Adaptive force balancing.*[9]

14:50–15:10 Coffee break.

15:10–16:00 *Exercise. Search and evasion.*[10]

[1] **nasa2012ws-Lec01v02.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] **nasa2012ws-Lec02.pdf**

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

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

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

[7] **nasa2012ws-Lec03.pdf**

Supporting material:

(1) *IGDT*, section 3.2.1.

(2) Lecture Notes on Robustness and Opportuneness (\risk\lectures\ro.tex), section 6.

[8] Problem Set on Robustness and Opportuneness (ps2-02.tex), #41.

[9] Problem Set on Robustness and Opportuneness (ps2-02.tex) #55.

[10] Problem Set on Robustness and Opportuneness (ps2-02.tex) #51(a), (b).

Day 2 Tuesday 11 September 2012

MORNING

09:00–9:50 *Lecture 4. Optimizer's Curse: An Info-Gap Response.*[11]

- Why best-model optimization is not a good bet if the best model is highly uncertain.[12]

10:00–10:50 *Lecture 5. Estimation and Forecasting.*[13]

- Use regression to predict with preliminary data from an unstable process.[14]

11:10–12:00 *Lecture 6. Info-Gap Statistics.*[15]

- Embedding a statistical test in an info-gap robustness analysis.
- Distributional uncertainty.
- Statistical test of the mean with distributional uncertainty.[16]
- Test of false nulls with uncertain sampling distribution.[17]

LUNCH 12:00–13:00

AFTERNOON

13:00–13:50 *Exercise: Braking system.*[18]

14:00–14:50 *Exercise: Choosing between two discrete lotteries.*[19]

14:50–15:10 Coffee break.

15:10–16:00 *Exercise: Accelerated lifetime testing.*

- Background.[20]
- Exercise.[21]

Day 3 Wednesday 12 September 2012

MORNING

09:00–10:00 *Brainstorming on mini-projects.*

10:00–12:00 *Guided independent work on mini-projects.*

LUNCH 12:00–13:00

AFTERNOON

13:00–14:00 PUBLIC LECTURE: *Model-Based Planning for an Uncertain Future: An Info-Gap Approach.*[22]

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

Day 4 Thursday 13 September 2012

MORNING

09:00–11:00 *Guided independent work on mini-projects.*

11:00–12:00 *Preliminary reports on mini-projects.*

LUNCH 12:00–13:00

13:00–16:00 *Guided independent work on mini-projects.*

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[11] **nasa2012ws-Lec04.pdf**

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

[13] **nasa2012ws-Lec06v02.pdf**.

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

[15] **nasa2012ws-Lec05.pdf**

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

[17] (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.

[18] Problem Set on Robustness and Opportuneness (ps2-02.tex) #28.

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

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

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

[22] nasa2012-01.pdf