



4-Day Workshop on
Info-Gap Theory and Its Applications in Engineering

26–29 June 2017
UNICAMP
Sao Paulo, Brazil

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Workshop Rationale Scientists, engineers, policy planners and analysts use measurements and science-based models to design systems, evaluate reliability, and make plans and policies. However, models may be simpler than reality, causal factors may be unknown, measurements may err or be incomplete, and systems may change over time in unknown ways. Probability is useful for modeling and managing some of these uncertainties. However some uncertainties are *info-gaps*: disparities between what *is known* and what *needs to be known* in order to make good decisions. For instance, we sometimes do not know the correct probability distribution or all of the relevant physical mechanisms such as non-linearities or time dependencies. This workshop studies info-gap theory for modeling and managing uncertainties in planning, design and decision problems. The workshop emphasizes the added value of an info-gap analysis as well as its limitations, and the integration of info-gap theory with probabilistic analysis.

Workshop Structure This workshop has three components. *Lectures* use simple examples to illustrate the info-gap method for analyzing risk and prioritizing choices when faced with severe uncertainty. *Exercises* help the participants to master the operational aspects of info-gap theory. The first two days are devoted to lectures and exercises. The last two days are devoted to *mini-projects* that are formulated and implemented by the participants, in small groups, on topics of their choice such as highly simplified versions of projects they work on elsewhere. This facilitates the internalization of the concepts and methods learned, their integration with other methods familiar to the participants, and their application to problems of interest to the participants.

The Instructor

Dr. Yakov Ben-Haim initiated and developed info-gap decision theory for modeling and managing severe uncertainty. Info-gap theory is applied in engineering, biological conservation, economics, project management, climate change management, national security, medicine, and other areas. He has been a visiting scholar in Australia, Austria, Canada, England, France, Germany, Italy, Japan,

Korea, Netherlands, Norway, and the US. He has lectured at universities, medical and technological research institutions and central banks around the world. He has published more than 100 articles and 5 books. He is a professor of mechanical engineering and holds the Yitzhak Moda'i Chair in Technology and Economics at the Technion—Israel Institute of Technology.

The Participants Scientists, engineers and analysts involved in risk analysis, reliability assessment, planning and design in engineering, project management, and related areas.

Brief Outline

Day 1 Monday 26 June 2017

MORNING

09:00–09:50 *Lecture 1. Info-gap theory: Overview and examples.*

10:00–10:50 *Lecture 2. Info-Gap Robustness of a Beam With Uncertain Load.*

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 3. Probabilistic reliability with info-gap uncertainty.*

LUNCH 12:10–13:40

AFTERNOON

13:40–14:30 *Exercise 1. Trigger mechanism.*

14:40–15:30 *Exercise 2. Adaptive force balancing.*

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 3. Cantilever.*

Day 2 Tuesday 27 June 2017

MORNING

09:00–09:50 *Lecture 4. Vibration suppression with uncertain load.*

10:00–10:50 *Lecture 5. Estimation with info-gap uncertainties.*

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 6. Safety factors and info-gap robustness.*

LUNCH 12:10–13:40

AFTERNOON

13:40–14:30 *Exercise 4. Gap-closing electrostatic actuators.*

14:40–15:30 *Exercise 5. Stress concentration factor.*

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 6. Uncertain linear elasticity.*

Day 3 Wednesday 28 June 2017

MORNING

09:00–09:45 *Brainstorm and define problems. Form small mini-project working groups.*

09:45–12:10 *Working groups formulate and develop robust info-gap solutions.*

LUNCH 12:10–13:40

AFTERNOON

13:40–15:50 *Working groups continue solution development.*

15:50–16:50 *Working groups present preliminary results.*

Day 4 Thursday 29 June 2017

MORNING

9:00–12:10 *Working groups continue solution development.*

LUNCH 12:10–13:40

AFTERNOON

13:40–15:50 *Working groups continue solution development.*

15:50–16:50 *Working groups present further results.*

Detailed Outline

Day 1 Monday 26 June 2017

MORNING

09:00–09:50 *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. Info-Gap Robustness of a Beam With Uncertain Load.*³

- Uncertain spatial distributions of load.⁴
- Info-gap models of uncertainty: uniform, envelope, Fourier ellipsoid.⁵

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 3. Probabilistic reliability with info-gap uncertainty.*⁶

LUNCH 12:10–13:40

AFTERNOON

13:40–14:30 *Exercise 1. Trigger mechanism.*⁷

14:40–15:30 *Exercise 2. Adaptive force balancing.*⁸

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 3. Cantilever.*⁹

Day 2 Tuesday 27 June 2017

MORNING

09:00–09:50 *Lecture 4. Vibration suppression with uncertain load.*¹⁰

10:00–10:50 *Lecture 5. Estimation with info-gap uncertainties.*¹¹

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 6. Safety factors and info-gap robustness.*¹²

LUNCH 12:10–13:40

AFTERNOON

¹**Lecture 1 notes:** brazil2017lec01-001.pdf

○ Many simple examples of info-gap analyses are found in section 3.2 of: Yakov Ben-Haim, 2006, *Info-gap Decision Theory: Decisions Under Severe Uncertainty*, 2nd edition, Academic Press, London (henceforth *IGDT*).

²*IGDT*, sections 2.2 and 2.3.

³**Lecture 2 notes:** brazil2017lec02-001.pdf

⁴Yakov Ben-Haim, 1996, *Robust Reliability in the Mechanical Sciences*, Springer, sections 3.1, 3.2.

⁵○ *IGDT*, section 2.5.

○ Yakov Ben-Haim, *Info-Gap Economics: An Operational Introduction*, (hencefore *IGE*), chap. 7.

⁶**Lecture 3 notes:** brazil2017lec03-001.pdf.

○ *IGDT*, section 3.2.3.

⁷**Exercise file** ps2p41.pdf. Based on ps2-02.tex #41.

⁸**Exercise file** ps2p55.pdf. Based on ps2-02.tex #55.

⁹**Exercise file** ps2p53.pdf. Do parts (a)–(d). Based on ps2-02.tex #53.

¹⁰**Lecture 4 notes:** brazil2017lec04-001.pdf

○ *IGDT*, section 3.3.1.

¹¹**Lecture 5 notes:** brazil2017lec05-001.pdf

○ *IGDT*, section 3.2.13.

○ *IGE*, chapter 6.

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

¹²**Lecture 6 notes:** brazil2017lec06-001.pdf.

○ Yakov Ben-Haim, 2005, Info-gap decision theory for engineering design. Or: Why 'good' is preferable to 'best', in *Engineering Design Reliability Handbook*, Edited by E. Nikolaidis, D. Ghiocel and Surendra Singhal, CRC Press.

13:40–14:30 *Exercise 4. Gap-closing electrostatic actuators.*¹³

14:40–15:30 *Exercise 5. Stress concentration factor.*¹⁴

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 6. Uncertain linear elasticity.*¹⁵

Day 3 Wednesday 28 June 2017

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09:00–09:45 *Brainstorm and define problems. Form small mini-project working groups.*

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AFTERNOON

13:40–15:50 *Working groups continue solution development.*

15:50–16:50 *Working groups present preliminary results.*

Day 4 Thursday 29 June 2017

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9:00–12:10 *Working groups continue solution development.*

LUNCH 12:10–13:40

AFTERNOON

13:40–15:50 *Working groups continue solution development.*

15:50–16:50 *Working groups present further results.*

Project Guidelines

1. Preliminary advice.
 - (a) Keep it simple.
 - (b) Write it up.
2. The story (English or Portuguese).
 - (a) Problem statement.
 - (b) Goals.
 - (c) Uncertainties.
 - (d) Decisions to be made:
 - i. What must we decide about?
 - ii. What are the options?
3. Math: Formulation.
 - (a) System Model.
 - (b) Performance requirements.
 - (c) Uncertainty model.
 - (d) Robustness definition (and perhaps opportuneness).
4. Math: Analysis.
 - (a) Evaluate the robustness function (analytical or numerical).
 - (b) Sketch or plot the robustness curves for alternative decisions.
5. Interpretation (English or Portuguese).
 - (a) Interpret the robustness curves.
 - (b) Make a decision, or start over.

¹³**Exercise file** ps2p72.pdf. Based on ps2-02.tex #72.

¹⁴**Exercise file** ps2p80.pdf. Based on ps2-02.tex #80.

¹⁵**Exercise file** ps2p89.pdf. Based on ps2-02.tex #89.

Selected Sources: Info-gap theory and applications

Books:

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.

Foundations of info-gap theory:

3. Yakov Ben-Haim, 2012, Doing Our Best: Optimization and the Management of Risk, *Risk Analysis*, 32(8): 1326–1332.
4. Yakov Ben-Haim, 2012, Why risk analysis is difficult, and some thoughts on how to proceed, *Risk Analysis*, 32(10): 1638–1646.
5. 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.

Engineering design:

6. Korteling, B., Dessai, S., Kapelan, Z., 2012, Using information-gap decision theory for water resources planning under severe uncertainty, *Water Resources Management*, 27(4): 1149–1172.
7. David Hambling, 5 Sept. 2012, Self-Defense for the Self-Driving Car, *Popular Mechanics*, Online version:
<http://www.popularmechanics.com/military/a8093/self-defense-for-the-self-driving-car-12410682/>
Selection from article: <http://tx.technion.ac.il/~yakov/IGT/hambling2012selection.html>
8. M.Pasquali, C.J.Stull and C.R.Farrar, 2015, Info-gap robustness of an input signal optimization algorithm for damage detection, *Mechanical Systems and Signal Processing*, 50–51: 1–10.

Environmental protection:

9. Jim W. Hall, Robert J. Lempert, Klaus Keller, Andrew Hackbarth, Christophe Mijere, and David J. McInerney, 2012, Robust Climate Policies Under Uncertainty: A Comparison of Robust Decision Making and Info-Gap Methods, *Risk Analysis*, 32(10): 1657–1672.
10. Dylan R. Harp and Velimir V. Vesselinov, 2013, Contaminant remediation decision analysis using information gap theory, *Stochastic Environmental Research and Risk Assessment*, 27(1): 159–168.
11. Yemshanov, Denys, Frank H. Koch, Yakov Ben-Haim and William D. Smith, 2010, Detection capacity, information gaps and the design of surveillance programs for invasive forest pests, *Journal of Environmental Management*, 91: 2535–2546.

Public policy:

12. Yakov Ben-Haim, Craig Osteen and L. Joe Moffitt, 2013, Policy Dilemma of Innovation: An Info-Gap Approach, *Ecological Economics*, 85: 130–138.

National Security:

13. Yakov Ben-Haim, Policy neutrality and uncertainty: An info-gap perspective, *Intelligence and National Security*, to appear.
14. Yakov Ben-Haim, Uncertainty and deterrence, *Air and Space Power Journal — A&F*, to appear.
15. Yakov Ben-Haim, 2015, Dealing with uncertainty in strategic decision-making, *Parameters*, US Army War College Quarterly, 45(3) Autumn 2015.
16. Yakov Ben-Haim, 2014, Strategy selection: An info-gap methodology, *Defense & Security Analysis*, 30(2): 106–119.

17. Lior Davidovitch and Yakov Ben-Haim, 2008, Is your profiling strategy robust? *Law, Probability and Risk*, 10: 59–76.

Medicine:

18. Yakov Ben-Haim, Nicola M. Zetola and Clifford Dacso, 2012, Info-Gap Management of Public Health Policy for TB with HIV-Prevalence, *BMC Public Health*, 12: 1091.

DOI: 10.1186/1471-2458-12-1091, URL: <http://www.biomedcentral.com/1471-2458/12/1091>

Info-gap statistics:

19. Yakov Ben-Haim, Miriam Zacksenhouse, Ronit Eshel, Raphael Levi, Avi Fuerst and Wayne Bentley, 2014, Failure detection with likelihood ratio tests and uncertain probabilities: An info-gap application, *Mechanical Systems and Signal Processing*, vol. 48, pp.1–14

20. Yakov Ben-Haim, 2011, Interpreting null results from measurements with uncertain correlations: An info-gap approach, *Risk Analysis*, 31(1): 78–85.

More references, background material, links: <http://info-gap.com>