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Six Lectures on Info-Gap Theory: Decisions Under Severe Uncertainty

Info-gap theory is a method for analysis, planning, decision and design under uncertainty. The future may differ from the past, so our models are may err in ways we cannot know. Our data may lack evidence about surprises: catastrophes or windfalls. 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 to engineering, biological conservation, financial and monetary economics, project management, medicine and homeland security.

These lectures introduce the audience to info-gap theory for decisions under severe uncertainty. The first three lectures provide an overview of concepts and applications in a range of disciplines. The second three lectures explore several topics in engineering analysis and design.

In these lectures we will consider the following topics.

The art of uncertainty modelling. Quantitative models and data, as well as conceptual understanding, are important in formulating decisions. Often the uncertainties surrounding these entities are subtle and require careful modelling in themselves. Info-gap models of uncertainty are useful for representing severe uncertainty.

Preference reversal under competition. Numerous paradoxes of decision under uncertainty—Ellsberg, Allais, and others—entail reversal of preferences between options. We explain how info-gap robust-satisficing provides an explanation.

Relation between robust-satisficing and min-max. These strategies are interchangeable as tools for *describing observed behavior* of an agent. However, they can lead to very different choices when used by an agent to *select an action,* depending on the agent's beliefs. We explain the *observational equivalence* and *behavioral difference* between these decision strategies.

Robustness and the probability of survival. Evidence suggests that agents in uncertain competition do not always try to optimize, but rather try to *satisfice* their outcomes. We discuss conditions for sub-optimal robust-satisficing being equivalent to maximizing the probability of survival.

Opportuneness: The other side of uncertainty. Uncertainty can be either *pernicious* (threatening failure), or *propitious* (offering windfall). We discuss the relation between info-gap robust-satisficing and opportune-windfalling, and show how these strategies can be combined in decision making.

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Place: Université de Franche-Comté, Besançon, France.
Instructor: Yakov Ben-Haim.
Format: Each lecture has two 50-minute sessions.
Detailed outline: See page 2.
References: See below and the footnotes.

Brief Outline

Lecture 1: Info-gap uncertainty and a few examples of the robust-satisficing strategy.
Lecture 2: Robustness and the probability of success.
Lecture 3: Statistical planning and inference with info-gaps.
Lecture 4: Design of a vibrating cantilever.
Lecture 5: Model up-dating of an elastic system.
Lecture 6: Structural reliability with uncertain probability.

Source Material on Info-Gap Theory

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

• 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.

• Yakov Ben-Haim, 2007, Peirce, Haack and Info-gaps, appearing in *Susan Haack, A Lady of Distinctions: The Philosopher Responds to Her Critics,* edited by Cornelis de Waal, Prometheus Books, Amherst, New York.

• Burgman, Mark, 2005, *Risks and Decisions for Conservation and Environmental Management,* Cambridge University Press, Cambridge.

• John K. Stranlund and Yakov Ben-Haim, 2008, Price-based vs. quantity-based environmental regulation under Knightian uncertainty: An info-gap robust satisficing perspective, *Journal of Environmental Management,* 87: 443–449.

• David R. Fox, Yakov Ben-Haim, Keith R. Hayes, Michael McCarthy, Brendan Wintle, Piers Dunstan, 2007, An info-gap approach to power and sample size calculations, *Environmetrics,* vol. 18, pp.189–203.

• http://www.technion.ac.il/yakov/IGT/igt.htm

Detailed Outline

Lecture 1: *Info-gap uncertainty and a few examples of the robust-satisficing strategy.*

- Info-gaps and probabilities: Two-envelope paradox, Keynes' riddle.[1]
- Expected utility, info-gaps, and saving the Sumatran Rhino.[2]
- Monetary policy with model uncertainty. Robustness and opportuneness.[3]

Lecture 2: *Robustness and the probability of success.*

- Foraging by animals (or stock brokers): Robust-satisficing and survival.[4]
- Forecasting: Using sub-optimal models.[5]
- Ellsberg's paradox: An Info-gap explanation.[6]

Lecture 3: *Statistical planning and inference with info-gaps.*

- Choosing a sample size with uncertain sampling distribution.[7]
- Testing the mean with distributional uncertainty.[8]

Lecture 4: *Design of a vibrating cantilever.*

- Conceptual design with load uncertainty. Robustness and opportuneness.[9]
- Exercise using `GapZapper.`

Lecture 5: *Model up-dating of an elastic system.*

- Estimating spring stiffness with uncertain non-linearity.[10]
- Exercise using `GapZapper.`

Lecture 6: *Structural reliability with uncertain probability.*

- One-dimensional system.[11]
- Exercise using `GapZapper.`

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[1] ◦ Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., sections 2.2, 2.5.
◦ Y. Ben-Haim, 2004, Uncertainty, probability and information-gaps, *Reliab. Eng. & System Safety,* 85: 249–266.
◦ Lecture Notes on Info-Gap Uncertainty (\risk\lectures\igunc.pdf), pp.2–11.

[2] ◦ Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., section 10.3.
◦ H.M. Regan, Y. Ben-Haim, B. Langford, W.G. Wilson, P. Lundberg, S.J. Andelman, M.A. Burgman, 2005, Robust decision making under severe uncertainty for conservation management, *Ecol. Appl.,* vol.15(4): 1471–1477.
◦ Lecture Notes on Conservation Management (\risk\lectures\rhino.pdf), pp.1–8.

[3] ◦ Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., section 3.2.8.
◦ Akram, Q.F., Y. Ben-Haim, and O. Eitrheim, 2006, Managing uncertainty through robust-satisficing monetary policy. Norges Bank Working papers, ANO 2006/10. Oslo, Norway.
◦ Y. Ben-Haim, Akram, Q.F., and O. Eitrheim, 2007, Monetary policy under uncertainty: Min-max vs robust-satisficing strategies, Norges Bank Working Papers, ANO 2007/6, Oslo, Norway.
◦ Lecture Notes: Policy Selection–Simple Example (\talks\lib\netherland2007.pdf) section 3 (policy01.tex).

[4] ◦ Yohay Carmel and Yakov Ben-Haim, 2005, Info-gap robust-satisficing model of foraging behavior: Do foragers optimize or satisfice?, *American Naturalist,* 166: 633–641.
◦ Yakov Ben-Haim, 2006, *Info-Gap Decision Theory,* 2nd ed., section 11.4.
◦ Lecture Notes on Robust-Satisficing Behavior(\risk\lectures\rsb01.pdf) sections 5.1, 5.2.

[5] ◦ Yakov Ben-Haim, Info-gap forecasting and the advantage of sub-optimal models, *Eur. J. Oper. Res.,* to appear.
◦ Lecture Notes on Info-Gap Estimation and Forecasting (\risk\lectures\estim01.pdf) section 3.

[6] ◦ Yakov Ben-Haim, *Info-Gap Decision Theory,* 2nd ed., section 11.1.
◦ Lecture Notes on Robust-Satisficing Behavior (\risk\lectures\rsb01.pdf) section 1.

[7] ◦ David R. Fox, Yakov Ben-Haim, Keith R. Hayes, Michael McCarthy, Brendan Wintle, Piers Dunstan, 2007, An info-gap approach to power and sample size calculations, *Environmetrics,* vol. 18, pp.189–203.
◦ Lecture Notes on Acceptance Testing (\reltest\acctes.pdf) sects. 8.1, 8.2.

[8] ◦ Lecture Notes on Acceptance Testing (\reltest\acctes.pdf) section 9.

[9] ◦ Yakov Ben-Haim, 2006, *Info-Gap Decision Theory,* 2nd ed., section 5.3.
◦ Lecture Notes on Robustness and Opportuneness (\risk\lectures\ro.pdf) section 6.

[10] ◦ Yakov Ben-Haim, 2006, *Info-Gap Decision Theory,* 2nd ed., section 3.2.13, chapter 8.
◦ Problem Set on Robustness and Opportuneness (\risk\homework\ps2_rk.pdf), #38.

[11] ◦ Yakov Ben-Haim, 2006, *Info-Gap Decision Theory,* 2nd ed., sections 3.2.3, 10.2.
◦ Lecture Notes on Hybrid Uncertainties (\risk\lectures\hybunc.pdf) sections 2.1, 2.2.