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3-Day Intensive Course on

Info-Gap Theory and Its Applications in Epidemiology and Public Health

Tuesday, Wednesday and Friday, 5, 6 and 8 September, 2023
Pierre Louis Institute for Epidemiology and Public Health
Faculty of Medicine Saint-Antoine, 3rd Floor, room 301.
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Contents

Course Rationale Public health planners, policy makers, scientists, and analysts use data and science-based models to design programs and policies and to evaluate their feasibility and reliability. However, models may be simpler than reality, causal factors may be unknown, data 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 social-psychological mechanisms that may be complex, non-linear and time dependent. This course studies info-gap theory for modeling and managing uncertainties in planning, design and decision problems. The course emphasizes the added value of an info-gap analysis as well as its limitations, and the integration of info-gap theory with probabilistic analysis.

Course Structure This course has three components. *Lectures* use simple examples to illustrate the info-gap method for prioritizing one's alternatives when facing deep uncertainty. *Exercises* help the participants to master the operational aspects of info-gap theory. Lectures and exercises occupy the first two days. The third day is devoted to *mini-projects* that are formulated and implemented by the participants, in small groups, on topics of their choice such as 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.

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The Instructors

Dr. Yakov Ben-Haim initiated and developed info-gap decision theory for modeling and managing deep 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 120 articles and 6 books. He is a professor emeritus of mechanical engineering and held the Yitzhak Moda'i Chair in Technology and Economics at the Technion—Israel Institute of Technology.

Dr. Nataliya Rybnikova is a postdoctoral researcher at the Technion — Israel Institute of Technology. She is currently working on applying the info-gap theory to epidemiological problems. She is the author of more than 30 articles and book chapters.

The Participants Analysts, planners and scholars from various fields who are involved in quantitative policy formulation and assessment in the fields of public health, social psychology, epidemiology of mental health, and related areas.

Brief Outline

Day 1

  MORNING

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

    10:00–10:50 *Lecture 2. Epidemiology with uncertainty: Response to bio-terror.*[2]

    10:50–11:20 Coffee break.

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

  LUNCH 12:10–13:40

  AFTERNOON

    13:40–14:30 *Exercise 1. Epidemiology with info-gaps.*[4]

    14:40–15:30 *Exercise 2. Multi-site adverse events.*[5]

    15:30–16:00 Coffee break.

    16:00–16:50 *Exercise 3. Transmission in an uncertain medium.*[6]

Day 2

  MORNING

    09:00–09:50 *Lecture 4. Statistical inference with info-gaps in underlying processes.*[7]

    10:00–10:50 *Lecture 5. Linear regression and forecasting with info-gaps.*[8]

    10:50–11:20 Coffee break.

    11:20–12:10 *Lecture 6. Case study: Info-gapping an epidemiological analysis.*

  LUNCH 12:10–13:40

  AFTERNOON

    13:40–14:30 *Exercise 4. Allocation of scarce resource.*[9]

    14:40–15:30 *Exercise 5. Spatial monitoring.*[10]

    15:30–16:00 Coffee break.

    16:00–16:50 *Exercise 6. Single hypothesis test.*[11]

Day 3

  MORNING

    09:00–09:40 *Lecture 7. Qualitative Analysis of Robustness: Conceptual Proxies.*[12]

    09:40–10:10 *Brainstorm and define problems. Form small mini-project working groups.*

    10:10–12:10 *Working groups formulate and implement robust info-gap solutions.*

  LUNCH 12:10–13:40

  AFTERNOON

    13:40–16:00 *Working groups continue solution development.*

    16:00–16:50 *Working groups present preliminary results.*

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[1]**Lecture 1 slides:** paris2023Lec01-001.pdf

[2]**Lecture 2 slides:** paris2023Lec02-001.pdf

[3]**Lecture 3 slides:** paris2023Lec03-002.pdf

[4]**Exercise 1:** \lectures\info-gap-methods\homework\ps2-02.tex #105.

[5]**Exercise 2:** ps2-02.tex #103 (a), (b).

[6]**Exercise 3:** ps2-02.tex #48.

[7]**Lecture 4 slides:** paris2023Lec04-001.pdf

[8]**Lecture 5 slides:** paris2023Lec05-002.pdf

[9]**Exercise 4:** ps2-02.tex #94 (a), (b).

[10]**Exercise 5:** ps2-02.tex #33.

[11]**Exercise 6:** \lectures\reltest\hwacc.tex #13.

[12]**Lecture 7 slides:** paris2023Lec06-001.pdf

Detailed Outline

Day 1

MORNING

09:00–09:50 *Lecture 1. Info-gap theory: Overview and examples.*[13]
- ○ Examples of deep info-gaps.
- ○ Principle of indifference.[14] 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. Epidemiology with uncertainty: Response to bio-terror.*[15]
- ○ Use models and data to ameliorate impact of bio-terror attack.
- ○ The challenge: Info-gaps:
  - — Event scenario.
  - — Mass psychology.
  - — Epidemiological complexity.
  - — Model error and incompleteness.
  - — Data deficiency.

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 3. Probabilistic reliability with info-gap uncertainty.*[16]
- ○ Reliability is the probability of success.
- ○ Sometimes the probability distribution is highly uncertain, so the reliability is uncertain.
- ○ We discuss an info-gap response.

LUNCH 12:10–13:40

AFTERNOON

13:40–14:30 *Exercise 1. Epidemiology with info-gaps.*[17]

14:40–15:30 *Exercise 2. Multi-site adverse events.*[18]

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 3. Transmission in an uncertain medium.*[19]

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[13]**Lecture 1 notes:** paris2023Lec01-001.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*).
- ○ Qualitative non-technical discussion of info-gap decision theory and its applications is found in Yakov Ben-Haim, 2018, *Dilemmas of Wonderland: Decisions in the Age of Innovation,* Oxford University Press.

[14]*IGDT*, sections 2.2 and 2.3.

[15]**Lecture 2 notes:** paris2023Lec02-001.pdf
- ○ *IDGT* section 3.2.11.
- ○ Anna Yoffe and Yakov Ben-Haim, An info-gap approach to policy selection for bio-terror response, IEEE International Conference on Intelligence and Security Informatics, ISI 2006, San Diego, CA, USA, May 23–24, 2006, pp.554-559. Also appearing in: *Lecture Notes in Computer Science,* Vol. 3975 LNCS, 2006, pp.554–559, Springer-Verlag, Berlin.

[16]**Lecture 3 notes:** paris2023Lec03-002.pdf
- ○ *IDGT* section 3.2.2, 3.2.3.
- ○ Yakov Ben-Haim, 1996, *Robust Reliability in the Mechanical Sciences,* Springer-Verlag, Berlin.

[17]**Exercise 1:** \lectures\info-gap-methods\homework\ps2-02.tex #105.

[18]**Exercise 2:** ps2-02.tex #103 (a), (b).

[19]**Exercise 3:** ps2-02.tex #48.

Detailed Outline

Day 2

MORNING

09:00–09:50 *Lecture 4. Statistical inference with info-gaps in underlying processes.*[20]

○ Testing a sample mean: Statistical Analysis.

○ Info-gapping the statistical analysis.

10:00–10:50 *Lecture 5. Linear regression and forecasting with info-gaps.*[21]

○ Optimal linear regression: Classical analysis.

○ Info-gapping classical linear regression.

○ Info-gap forecasting.

10:50–11:20 Coffee break.

11:20–12:10 *Lecture 6. Case study: Info-gapping an epidemiological analysis.*

○ TEMPO data from Corona and pre-Corona times.

LUNCH 12:10–13:40

AFTERNOON

13:40–14:30 *Exercise 4. Allocation of scarce resource.*[22]

14:40–15:30 *Exercise 5. Spatial monitoring.*[23]

15:30–16:00 Coffee break.

16:00–16:50 *Exercise 6. Single hypothesis test.*[24]

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[20]**Lecture 4 slides:** paris2023Lec04-001.pdf

[21]**Lecture 5 slides:** paris2023Lec05-002.pdf

○ Extensive discussion of estimation and forecasting in chap. 6 of Yakov Ben-Haim, *Info-Gap Economics: An Operational Introduction,* Palgrave Macmillan, 2010.

[22]**Exercise 4:** ps2-02.tex #94 (a), (b).

[23]**Exercise 5:** ps2-02.tex #33.

[24]**Exercise 6:** \lectures\reltest\hwacc.tex #13.

Project Guidelines

1. Preliminary advice.
    (a) Keep it simple.
    (b) Write it up.
2. The story, in English or French:
    (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, in English or French:
    (a) Interpret the robustness curves.
    (b) Make a decision, or start over.

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.
3. Yakov Ben-Haim, 2018, *The Dilemmas of* Wonderland*: Decisions in the Age of Innovation*, University of Oxford Press.

   Foundations of info-gap theory:

4. Yakov Ben-Haim, 2019, Info-gap decision theory, in V.A.W.J. Marchau, W.E. Walker, P. Bloemen, and S.W. Popper (eds.), *Decision Making Under Deep Uncertainty: From Theory to Practice,* Springer.
5. Yakov Ben-Haim, 2019, Assessing 'beyond a reasonable doubt' without probability: An info-gap perspective, *Law, Probability and Risk,* appearing online, https://doi.org/10.1093/lpr/mgy021.
6. Yakov Ben-Haim and Mike Smithson, 2018, Data-Based Prediction under Uncertainty: A Dual Approach. *Journal of Mathematical Psychology,* 87: 11–30.
7. Yakov Ben-Haim, 2017, Does a better model yield a better argument? An info-gap analysis, Proceedings of the Royal Society, A, 5 April 2017.
8. Yakov Ben-Haim, 2014, Order and indeterminism: An info-gap perspective, appearing in Error and Uncertainty in Scientific Practice, Marcel Boumans, Giora Hon and Arthur Petersen, eds., Pickering & Chatto Publishers, London, pp.157–175.
9. Yakov Ben-Haim, 2012, Doing Our Best: Optimization and the Management of Risk, *Risk Analysis*, 32(8): 1326–1332.

10. Yakov Ben-Haim, 2012, Why risk analysis is difficult, and some thoughts on how to proceed, *Risk Analysis,* 32(10): 1638–1646.

11. 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.

More sources on foundational issues: https://info-gap.technion.ac.il/foundations-and-philosophy.

Medicine:

12. Yakov Ben-Haim, 2020, Quantitative analysis for interpreting diagnostic tests for Covid-19: Rev. Thomas Bayes can help. 42nd Annual Meeting of the Society for Medical Decision Making, October 2020.

13. Chen, W.-L., Kan, C.-D., Yu, F.-M., Mai, Y.-C., Lin, C.-H., 2018, Life-threatening complication detection during hemodialysis using fractional order info-gap decision-making, *Intelligent Decision Technologies,* 12(1) pp.105–117.

14. 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

More sources on medical applications: https://info-gap.technion.ac.il/medicine/

Info-gap statistics:

15. 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

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

More sources on info-gap statistics: https://info-gap.technion.ac.il/statistics/

Environmental protection:

17. 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.

18. 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.

19. 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.

More sources on environmental protection: https://info-gap.technion.ac.il/biological-conservation/

Public policy:

20. Yakov Ben-Haim, 2021, Feedback for energy conservation: An info-gap approach, *Energy,* 223: 119957.

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

More references and background material on many info-gap applications: http://info-gap.com