A Formal Look at Info-Gap

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Abstract

Info-Gap is a (very) young theory for decision-making under severe uncertainty.

It presents itself as a new theory and claims that it is radically different from all current theories of decision-making under uncertainty.

Its claim to fame is that it offers a probability-free approach to uncertainty.

I show that, in actual fact, not only is Info-Gap's generic model not new, it is a simple instance of none other than ...the most famous model in decision-making under severe uncertainty, namely Wald's [1945] Maximin Model.

Furthermore, I also show that Info-Gap is fundamentally flawed in that it does not deal with severe uncertainty, it simply and unceremoniously ignores it.

Programme

Info-Gap: overview

- A relatively young theory (Ben-Haim [2001, 2006]).
- Claims to be new and radically different from all current theories for decision-making under uncertainty.
- Based on a probability-free uncertainty model.
- Does not represent the state of the art in decision theory.
- Fundamentally flawed: conceptually, methodologically and technically.
- An excellent example of how quickly things can go wrong.
- Based on a very rigid mathematical modeling paradigm.
- The University of Melbourne seems to be one of its major international strongholds!
- A formal examination of Info-Gap is long overdue!

A bit of history

- First encounter: An invitation to a seminar (3/8/03)
- Second encounter: Seminar (Ben-Haim, 2/9/03).
- Requests for comments on Info-Gap: 2/9/03 – present.
- Informal critique: 3/9/03 – present.
- Formal critique: 1/12/06 – present.
- Campaign launch: 31/12/06.
- First feedback from Ben-Haim: (Friday! 13/4/07).
- ACERA seminar: 4/5/07.
- On the agenda:
  - Seminars
  - Honours thesis
  - Conference presentations
  - Articles
  - Book

Executive Summary

- Decision-making under severe uncertainty is difficult.
- This is a very active area of research/practice.
- The Robust Optimization literature is very relevant.
- The Operations Research literature is very relevant.
- The Decision Theory literature is very relevant.
- The generic Info-Gap model is a simple vanilla instance of the classical Maximin Model [1945].
- Info-Gap is fundamentally flawed and is not suitable for decision-making under severe uncertainty.
- Practicing Info-gap amounts to voodoo decision-making.

Voodoo

Encarta online Encyclopedia

Voodoo n

1. A religion practiced throughout Caribbean countries, especially Haiti, that is a combination of Roman Catholic rituals and animistic beliefs of Dahomean enslaved laborers, involving magic communication with ancestors.
2. Somebody who practices voodoo.
3. A charm, spell, or fetish regarded by those who practice voodoo as having magical powers.
4. A belief, theory, or method that lacks sufficient evidence or proof.

Voodoo Decision-Making

Early reference,

> *Richard Tam, a visionary and entrepreneur, started iUniverse he once told me after seeing how major publishing companies deal in false scarcity and voodoo decision-making processes. "They don't know where – or who – their customers are. They have to find them all over again every time they need to market something new."*
>
> *Wednesday, August 28, 2002*
>
> http://blogs.salon.com/0001111/2002/08/28.html

Info-Gap

Info-Gap

Info-Gap

A Self-Portrait

> Info-gap decision theory is radically different from all current theories of decision under uncertainty. The difference originates in the modelling of uncertainty as an information gap rather than as a probability. The need for info-gap modeling and management of uncertainty arises in dealing with severe lack of information and highly unstructured uncertainty.
>
> Ben-Haim [2006, p.xii]

> In this book we concentrate on the fairly new concept of information-gap uncertainty, whose differences from more classical approaches to uncertainty are real and deep.
>
> Ben-Haim [2006, p. 11]

Info-Gap

Facts of Life

There are very serious (fatal?) gaps in Info-Gap. The following is a partial list:

- Info-Gap has serious misconceptions about the state of the art in decision-making under severe uncertainty.
- The generic Info-Gap model is a naive instant of the famous classical Wald's Maximin model [1945].
- Info-Gap is fundamentally flawed. It does not deal with severe uncertainty, it simply ignores it.
- Info-Gap is not suitable for decision-making under severe uncertainty.

A room with a view on

Decision-Making Under Severe Uncertainty

Info-Gap	*Decision Theory*
Robust Optimization	*Operations Research*

Generic Info-Gap Model

- Uncertainty region (set), $\mathfrak{U}$.
- A parameter u whose true value, u°, is unknown except that $u^\circ \in \mathfrak{U}$.
- A point estimate, $\tilde{u} \in \mathfrak{U}$, of u°.
- A parametric family of nested regions of uncertainty, $\mathcal{U}(\alpha, \tilde{u}) \subseteq \mathfrak{U}, \alpha \geq 0$, of varying size ($\alpha$), centered at $\tilde{u}$. That is, it is assumed that $\mathcal{U}(0, \tilde{u}) = \{\tilde{u}\}$ and that $\mathcal{U}(\alpha, \tilde{u})$ is non-decreasing with α, namely

$$\alpha'', \alpha' \in \mathbb{R}_+, \;\; \alpha'' > \alpha' \Longrightarrow \mathcal{U}(\alpha', \tilde{u}) \subseteq \mathcal{U}(\alpha'', \tilde{u}) \qquad (1)$$

- Set of feasible decisions, $\mathbb{Q}$.
- Reward function $R: \;\; \mathbb{Q} \times \mathfrak{U} \rightarrow \mathbb{R}$.
- Critical reward level, $r_c \in \mathbb{R}$.

Generic Info-Gap Model

Robustness of a decision

$$\hat{\alpha}(q, r_c) := \max \left\{ \alpha \geq 0 : r_c \leq \min_{u \in \mathcal{U}(\alpha, \tilde{u})} R(q, u) \right\} \tag{2}$$

Optimal robustness

$$\hat{\alpha}(r_c) := \max_{q \in \mathbb{Q}} \hat{\alpha}(q, r_c) \tag{3}$$

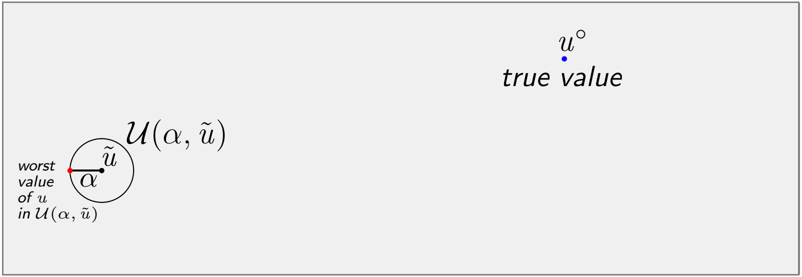
$$= \max_{q \in \mathbb{Q}} \max \left\{ \alpha \geq 0 : r_c \leq \min_{u \in \mathcal{U}(\alpha, \tilde{u})} R(q, u) \right\} \tag{4}$$

Generic Info-Gap Model

Complete Generic Model

$$\hat{\alpha}(r_c) := \max_{q \in \mathbb{Q}} \max \left\{ \alpha \geq 0 : r_c \leq \min_{u \in \mathcal{U}(\alpha, \tilde{u})} R(q, u) \right\} \qquad (5)$$

Region of Severe Uncertainty, $\mathfrak{U}$



Info-Gap

Complete Generic Model

$$\hat{\alpha}(r_c) := \max_{q \in \mathbb{Q}} \max \left\{ \alpha \geq 0 : r_c \leq \min_{u \in \mathcal{U}(\alpha, \tilde{u})} R(q, u) \right\} \qquad (6)$$

Fundamental FAQs

1. Is this new? — Definitely not!
2. Is this radically different? — Definitely not!
3. Does it make sense? — Definitely not!

So what is all this hype about Info-Gap, anyway?!

Good question!

Info-Gap

First Impression

Complete Generic Model

$$\hat{\alpha}(r_c) := \max_{q\in\mathbb{Q}} \max\left\{\alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u)\right\} \tag{7}$$

Observations

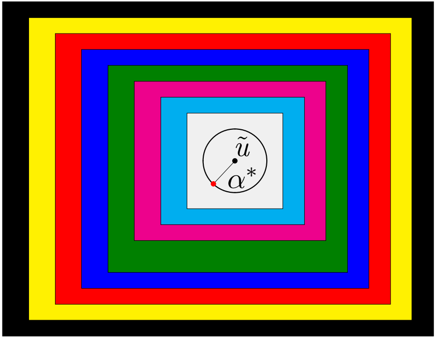
- This model is fundamentally flawed.
- It does not deal with severe uncertainty, it simply and unceremoniously ignores it.
- The analysis is invariant with $\mathfrak{U}$: the same solution for all $\mathfrak{U}$ such that $\mathcal{U}(\hat{\alpha}(r_c)) \subseteq \mathfrak{U}$.
- This is a lemon.

Info-Gap

Complete Generic Model

$$\alpha^* := \max_{q \in \mathbb{Q}} \ \max \left\{ \alpha \geq 0 : r_c \leq \min_{u \in \mathcal{U}(\alpha, \tilde{u})} R(q, u) \right\} \qquad (8)$$

Fundamental Flaw



Classical Decision Theory

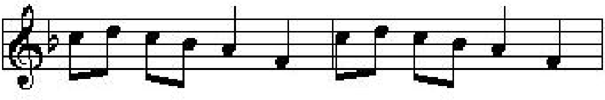
Info-Gap

Decision Theory

Robust Optimization

Operations Research

Classical Decision theory



Eg.

620-262: Decision Making

A Simple Problem

Good morning Sir/Madam:

I left on your doorstep four envelopes. Each contains some money. You are welcome to open any one of these envelopes and keep the money you find there.

Please note that as soon as you open an envelope, the other three will automatically self-destruct, so think carefully about which of these envelopes you should open.

To help you decide what you should do, I printed on each envelope the possible values of the amount of money (in Australian dollars) you may find in it. The amount that is actually there is equal to one of these figures.

Unfortunately the entire project is under severe uncertainty so I cannot tell you more than this.

Good luck!

Joe.

So What Do You do?

Example

Envelope	*Possible Amount (Australian dollars)*
$E1$	$20, 10, 300, 786$
$E2$	$2, 40000, 102349, 5000000, 99999999, 56435432$
$E3$	$201, 202$
$E4$	200

Vote!

Modeling and Solution

- What is a decision problem ?
- How do we model a decision problem?
- How do we solve a decision problem?

Decision Tables

Think about your problem as a table, where

- rows represents decisions
- columns represent the relevant possible states of nature
- entries represent the associated payoffs/rewards/costs

Example

Env	*Possible Amount ($AU)*				
$E1$	20	10	300	786	
$E2$	2	4000000	102349	500000000	56435432
$E3$	201	202			
$E4$	200				

Classification of Uncertainty

Classical decision theory distinguishes between three levels of uncertainty regarding the state of nature, namely

- Certainty
- Risk
- Strict Uncertainty

In our discussion

Strict Uncertainty $\equiv$ Severe Uncertainty $\equiv$ Ignorance $\equiv$ True Uncertainty

Severe Uncertainty

Classical decision theory offers two basic principles for dealing with situations involving severe uncertainty, namely

- Laplace's Principle (1825)
- Wald's Principle (1945)

Conceptually:

$$\text{Certainty} \overset{\text{Wald}}{\Longleftarrow} \boxed{\text{Severe Uncertainty}} \overset{\text{Laplace}}{\Longrightarrow} \text{Risk}$$

$$\Downarrow$$

Info-Gap
????

Bottom line: under severe uncertainty the estimate we have is a poor indicator of the true value and is likely to be substantially wrong.

Laplace's Principle of Insufficient Reason (1825)

Assume that all the states are equally likely, thus use a uniform distribution function (μ) on the state space and regard the problem as decision-making under risk.

Laplace's Decision Rule

$$\max_{d \in \mathbb{D}} \int_{s \in S_d} r(s, d)\mu(s)\,ds \qquad \text{Continuous case}$$

$$\max_{d \in \mathbb{D}} \frac{1}{|S_d|} \sum_{s \in S_d} r(s, d) \qquad \text{Discrete case}$$

Wald's Maximin Principle (1945)

Inspired by Von Neumann's [1928] Maximin model for 0-sum, 2-person games: Mother Nature is playing against you, hence apply the worst-case scenario. This transforms the problem into a decision-making under certainty.

Wald's Maximin Rule

$$\overset{\text{You!}}{\max_{d\in\mathbb{D}}} \ \overset{\text{Mama}}{\min_{s\in S_d}} \ f(d,s)$$

Historical perspective: William Shakespeare (1564-1616)

> *The gods to-day stand friendly, that we may,*
> *Lovers of peace, lead on our days to age!*
> *But, since the affairs of men rests still incertain,*
> *Let's reason with the worst that may befall.*
>
> *Julius Caesar, Act 5, Scene 1*

Laplace vs Wald

Example

Env	*Possible Amount ($AU)*				
$E1$	20	10	300	786	
$E2$	2	4000	102349	50000	56435
$E3$	201	202			
$E4$	200				

Example

Env	*Possible Amount ($AU)*					*Laplace*	*Wald*
$E1$	20	10	300	786		279	10
$E2$	2	4000	10234	50000	56435	24134.2	2
$E3$	201	202				201.5	201
$E4$	200					200	200

Laplace vs Wald

Example

Env	*Possible Amount ($AU)*					*Laplace*	*Wald*
$E1$	20	10	300	786		279	10
$E2$	2	4000	10234	50000	56435	24134.2	2
$E3$	201	202				201.5	201
$E4$	200					200	200

Severe Uncertainty

Warning!

- For obvious reasons, methodologies for decision-making under severe uncertainty are austere.
- There are no miracles in this business.
- The essential difficulty is: how do you sample the uncertainty region?
- If you are offered a methodology that is too good to be true,. . . it is!

Myths and Facts

Myth # 1

Classical decision theory does not offer probability-free approaches to decision-making under severe uncertainty.

Fact # 1

This is pure nonsense. Practically all introductory textbooks on decision theory discuss probability-free paradigms for decision-making under severe uncertainty. The most famous one is Wald's Maximin Model [1945].

Example

CHOICES

AN INTRODUCTION TO DECISION THEORY

Michael D. Resnik

1987

Chapter 1

Introduction

Example

Chapter 2

Decisions Under Ignorance

2-1 Preference Ordering

2-2 The Maximin Rule

2-3 The Minimax Regret Rule

2-4 The Optimism-Pessimism Rule

2-5 The Principle of Insufficient Reason

2-6 Too many Rules?

2-7 An application in Social Philosophy

2-8 References

Example

Chapter 3

Decisions Under Risk: Probability

3-1 Maximizing Expected Values

3-2 Probability Theory

2-3 Interpretations of Probability

2-8 References

Chapter 4

Decisions under Risk: Utility

4-1 Interval Utility Scales

. . .

Myths and Facts

Myth # 2

Info-Gap region of uncertainty is unbounded, therefore there is no worst case, and info-gap is not Maximin. (Ben-Haim [2005]).

Fact # 2

This is pure nonsense.

Comments:

- There could be a worst case even if the region of uncertainty is unbounded.
- There is a worst case in all problems where Info-Gap yields a solution (Sniedovich [2006]).

Myths and Facts

620-161: Introductory Mathematics

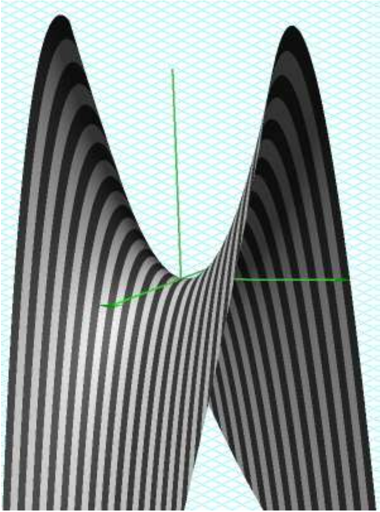
The most classical saddle point on $\mathfrak{Planet\ Earth}$ is associated with the unbounded region $\mathbb{R}^2$ and the function

$$f(x,y) := x^2 - y^2$$

The saddle point is the solution to the Maximin problem

$$z^* := \max_{y\in\mathbb{R}} \min_{x\in\mathbb{R}} \left\{ x^2 - y^2 \right\}$$

$$z^* := \max_{y \in \mathbb{R}} \min_{x \in \mathbb{R}} \left\{ x^2 - y^2 \right\}$$



Myths and Facts

Ben-Haim [2001-2006] confuses a number of aspects of the Info-Gap uncertainty model:

$$\alpha(r_c) := \max_{q\in\mathbb{Q}} \max\left\{\alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u)\right\}$$

- α is unbounded.
- $\mathcal{U}(\alpha,\tilde{u})$ is (???????) unbounded.
- $R(q,u)$ is (???????) unbounded.

Example (Ben-Haim [2006])

- $\mathcal{U}(\alpha,\tilde{u}) := \left\{u \in [0,1] : \left|\frac{u-\tilde{u}}{\tilde{u}}\right| \leq \alpha\right\} \ , \ \alpha \geq 0$
- α is unbounded.
- $\mathcal{U}(\alpha,\tilde{u}) \subseteq [0,1]$ is bounded.
- There is definitely a worst case!

Myths and Facts

Theorem

Info-Gap's uncertainty model is subject to a worst case.

Proof.

$$\hat{\alpha}(q, r_c) := \max_{\alpha \geq 0} \; G(\alpha) \cdot H(q, \alpha) \tag{9}$$

where

$$G(\alpha) := \alpha \;,\; \alpha \geq 0 \tag{10}$$

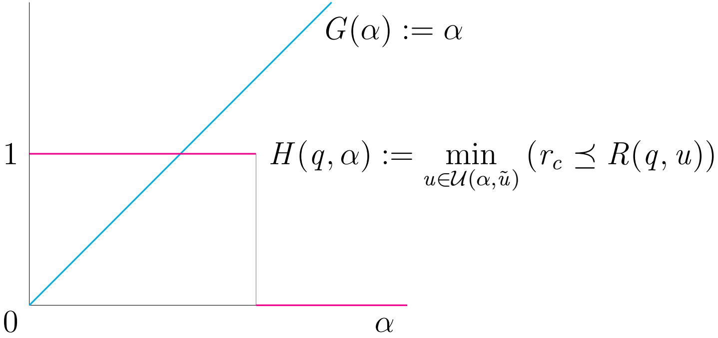
$$H(q, \alpha) := \min_{u \in \mathcal{U}(\alpha, \tilde{u})} (r_c \preceq R(q, u)) \;,\; \mathbb{Q}, \alpha \geq 0 \tag{11}$$

$$a \preceq b := \begin{cases} 1 & , \quad a \leq b \\ 0 & , \quad a > b \end{cases} \tag{12}$$

Clearly, $G(\alpha) \cdot H(q, \alpha) \in \{0, \alpha\}$. □

Myths and Facts

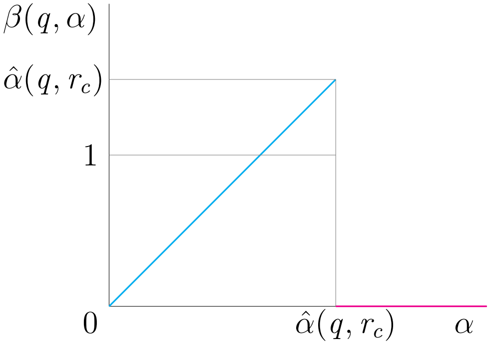
$$\hat{\alpha}(q, r_c) := \max_{\alpha \geq 0} \min_{u \in \mathcal{U}(\alpha, \tilde{u})} \alpha \cdot (r_c \preceq R(q, u))$$



Myths and Facts

$$\beta(q,\alpha) := G(\alpha)\cdot H(q,\alpha) = \alpha \cdot \min_{u\in\mathcal{U}(\alpha,\tilde{u})} (r_c \preceq R(q,u))$$

$$\in \{0,\alpha\}$$



Myths and Facts

Myth # 3

Info-Gap is a new theory that is radically different from all current theories for decision-making under severe uncertainty (Ben-Haim [2001, 2006])

Fact # 3

Info-Gap's generic model is neither new nor radically different. It is a simple instance of Wald's Maximin model (Sniedovich [2006])

Maximin	*Info-Gap*
$\max_{d\in\mathbb{D}} \min_{s\in S_d} f(d,s)$	$\max_{q\in\mathbb{Q}} \max \left\{\alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u)\right\}$

Myths and facts

Theorem (Sniedovich [2006])

Info-Gap's generic model is a simple Maximin Model.

Proof.

$$\alpha(r_c) := \max_{q\in\mathbb{Q}} \max \left\{ \alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u) \right\} \tag{13}$$

$$= \max_{q\in\mathbb{Q},\alpha\geq 0} \min_{u\in\mathfrak{U}(\alpha,\tilde{u})} \overbrace{\alpha\cdot(r_c \preceq R(q,u))}^{f(q,\alpha,u)} \tag{14}$$

$$a \preceq b := \begin{cases} 1 & , \quad a \leq b \\ 0 & , \quad a > b \end{cases} \tag{15}$$

□

Myths and Facts

Myth # 4

Info-Gap generates robust solutions for decision-making problems under severe uncertainty.

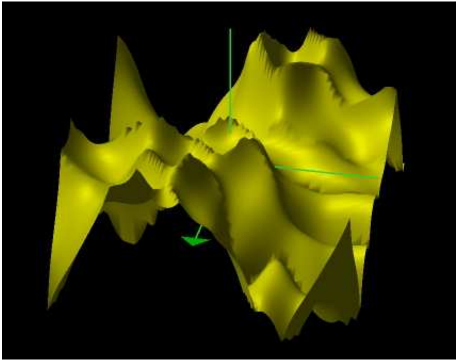
Fact # 4

There is no reason to believe that under severe uncertainty the solutions generated by Info-Gap are robust (see explanation and counter examples in Sniedovich [2006]).

Region of Severe Uncertainty, $\mathfrak{U}$

Myths and Facts

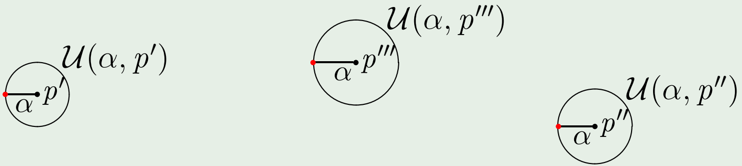
Note the difference between local and global optimization.



Myths and Facts

Comment

To obtain a robust solution under severe uncertainty you have to incorporate in the analysis a number of point estimates, making sure that they adequately represent the entire region of uncertainty, $\mathfrak{U}$.



See the Worst-Case Analysis and Robust Optimization literature for tips, guidelines and inspiration.

Myth and Facts

Algorithms for Worst-case Design and Applications to Risk Management

Rustem and Howe, [2002, p. xiii]

. . . If the forecaster tries to specify too many discrete forecasts, in an attempt to cover most possibilities, discrete minimax may yield too pessimistic strategies or even run into numerical, or computational, problems due to the resulting numerous scenarios. Similarly, as the upper and lower bounds on a range of forecasts get wider, to provide coverage to a wider set of possibilities, the minimax strategy may become pessimistic. Thus, scenarios have to be chosen with care, among genuinely likely values. The minimax strategy will then answer the legitimate question of what the best strategy should be, in view of the worst case . . .

Myths and Facts

Myth # 5

It is better to satisfice than to optimize.

Fact # 5

Any satisficing problem can be formulated as an (equivalent) optimization problem (Sniedovich [2006]).

Comments:

- Strictly and bluntly speaking, the assertion that satisficing is superior to optimizing is pure nonsense.
- What is important is what you optimize and what you satisfice.

Myths and facts

Theorem (Sniedovich [2006])

Any satisficing problem can be expressed as an (equivalent) optimization problem.

Proof.

Let I denote the universal indicator function:

$$I_X(x) := \begin{cases} 1 & , \quad x \in X \\ 0 & , \quad x \notin X \end{cases} \tag{16}$$

Then clearly,

$$x \in X \subseteq X' \Longleftrightarrow x = \arg\max_{x \in X'} I_X(x) \tag{17}$$

□

Myths and facts

Example

You win a game (AU$5,000,000) if you select an action $q \in \mathbb{Q}$ such that $17 \leq \sigma(q) \leq 21$, where σ is a given real-valued function on $\mathbb{Q}$.

Problem: Find a $q \in \mathbb{Q}$ such that $17 \leq \sigma(q) \leq 21$

This is typical satisficing model. Note that, in general, to win the game you do not necessarily optimize the score $\sigma(q)$ over $q \in \mathbb{Q}$. The following is an equivalent optimization model:

$$\max_{q \in \mathbb{Q}} \ 5w(q)$$

$$w(q) := \begin{cases} 1 & , \quad 17 \leq \sigma(q) \leq 21 \\ 0 & , \quad \textit{otherwise} \end{cases}$$

Myths and Facts

Myth # 6

Robust optimization is a contradiction in terms.

Fact # 6

Robust optimization is a well established area of optimization theory: more than 30-year old, and going strong!

Myths and Facts

Myth # 7

Info-gap decision theory provides a platform extending decision theory into a broad range of new problems.

Fact # 7

Info-Gap does not extend classical decision theory. Its generic model is an instance of the classical classical Maximin and its trade-off analysis is vanilla Pareto optimization.

Myths and Facts

Myth # 8

Info-Gap deals with severe uncertainty.

Fact # 8

Info-Gap does not deal with severe uncertainty. It ignores it. This involves:

- Replacing severe uncertainty by a very poor estimate of the parameter under consideration.
- Conducting standard maximin analysis in the neighborhood of this very poor estimate.

Correction:

$$\alpha(r_c) := \max_{q\in\mathbb{Q}} \max\left\{\alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u)\right\}$$

Info-Gap Interpretation

$\hat{\alpha}(q, r_c)$:= robustness of decision q given the required reward r_c.

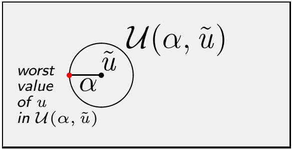
Correct interpretation

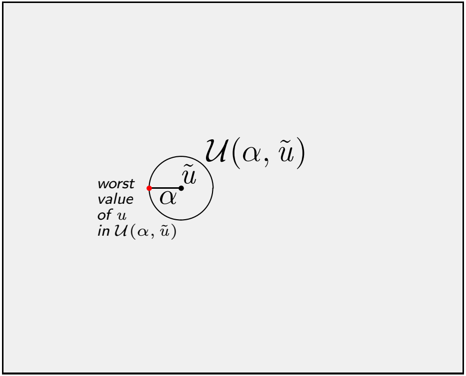
$\hat{\alpha}(q, r_c, \tilde{u})$:= robustness of decision q given the required reward r_c, in the neighborhood of the POOR estimate $\tilde{u}$ that is likely to be SUBSTANTIALLY WRONG.

Myth and Facts

Observation

The Info-Gap analysis is invariant with the actual size of the total region of uncertainty, $\mathfrak{U}$.
This is ridiculous.



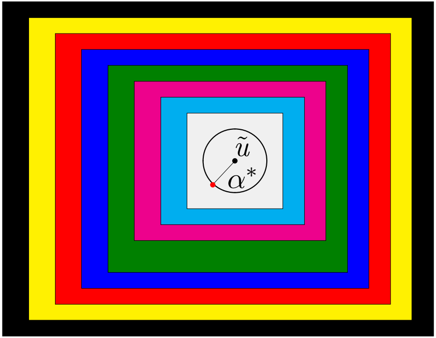


Info-Gap

Complete Generic Model

$$\alpha^* := \max_{q\in\mathbb{Q}} \max\left\{\alpha \geq 0 : r_c \leq \min_{u\in\mathcal{U}(\alpha,\tilde{u})} R(q,u)\right\} \tag{18}$$

Fundamental Flaw



Myths and Facts

Myth # 9

Info-Gap is about the gap between what we know (poor estimate) and what we need to know (true value).

Fact # 9

Info-Gap is not about the gap between what we know (poor estimate) and what we need to know(true value). It is about ignoring the gap between what we know (poor estimate) and what we need to know (true value).

Myths and Facts

Myth # 10

Info-Gap is a methodology for decision-making under severe uncertainty.

Fact # 10

Practicing Info-Gap amounts to voodoo decision-making:

1. Replacing severe uncertainty by a very poor estimate of the parameter under consideration.
2. Conducting standard maximin analysis in the neighborhood of this very poor estimate.

Voodoo

Encarta online Encyclopedia

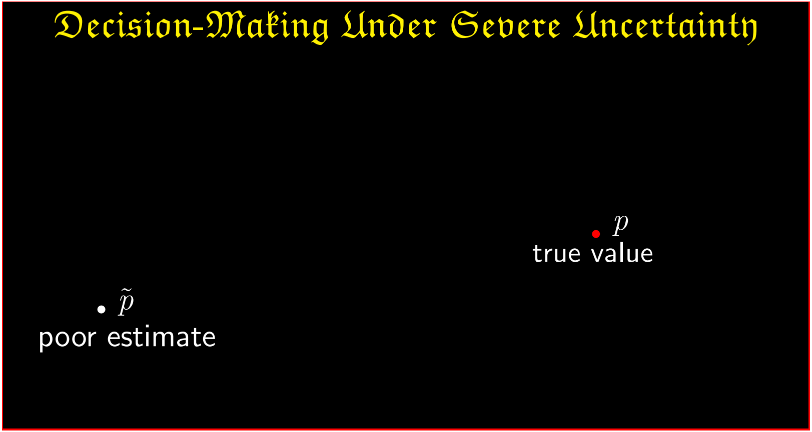
Voodoo n

1. A religion practiced throughout Caribbean countries, especially Haiti, that is a combination of Roman Catholic rituals and animistic beliefs of Dahomean enslaved laborers, involving magic communication with ancestors.
2. Somebody who practices voodoo.
3. A charm, spell, or fetish regarded by those who practice voodoo as having magical powers.
4. A belief, theory, or method that lacks sufficient evidence or proof.

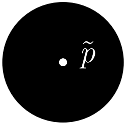
Conclusions

- Decision-making under severe uncertainty is difficult.
- This is a very active area of research/practice.
- The Robust Optimization literature is very relevant.
- The Operations Research literature is very relevant.
- The Decision Theory literature is very relevant.
- Info-Gap is neither new nor radically different.
- Info-Gap is fundamentally flawed and is not suitable for decision-making under severe uncertainty.
- Info-Gap exhibits a severe information-gap about the state of the art in decision-making under severe uncertainty.
- If we accept Info-Gap as a legitimate theory for decision-making under severe uncertainty, we in fact abolish the very active and relevant area of ...decision-making under severe uncertainty.

A thing to remember



A thing to remember



Off the record

The Ten Natural Laws of Operations Analysis

Bob Bedow, *Interfaces* 7(3), p. 122, 1979

1. Ignore the problem and go immediately to the solution, that is where the profit lies.
2. There are no small problems only small budgets.
3. Names are control variables.
4. Clarity of presentation leads to aptness of critique.
5. Invention of the wheel is always on the direct path of a cost plus contract.
6. Undesirable results stem only from bad analysis.
7. It is better to extend an error than to admit to a mistake.
8. Progress is a function of the assumed reference system.
9. Rigorous solutions to assumed problems are easier to sell than assumed solutions to rigorous problems.
10. In desperation address the problem.

Off the record

Join the Worst Case / Maximin Campaign

www.ms.unimelb.edu.au/~moshe/

I Love

me! mama!

$$v^* := \max_{d \in \mathbb{D}} \min_{s \in S_d} f(d, s)$$

Wald's Maximin Principle

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Q&A