Model-Based Planning for an Uncertain Future: An Info-Gap Approach

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Abstract

Quantitative models are used in design and strategic planning in all areas where systematic quantitative analysis is applicable, including engineering, economics, public policy, homeland security, biological conservation, medicine, and so on. Quantitative models bridge the gap between basic and applied science. Science-based modeling gives us the confidence to engage in complex projects and to manage serious risks. Models provide the tools to achieve great ends with limited resources. Models enable us to assess what can be achieved and how far we have yet to go. Models allow us to optimize.

Uncertainty is a major challenge in model-based design. Science-based models employ current knowledge and understanding, while the scientific process is on-going: understanding grows and theories improve. Models are also based on data from the past, and in those areas where historical processes are relevant—such as economics and social planning—the past does not necessarily reflect the future; things can change in fundamental ways.

Uncertainty has profound implications for use of models in design and planning, especially for the concept of optimization.

There is a moral imperative to do our best. Decision makers sometimes translate that to mean that we must attempt to achieve the best possible outcome, the highest level of performance, the greatest return on the investment. Competition, it is thought, favors those who achieve the most, and lower achievers are removed from the competition. In biological evolution, in commercial markets, and in the market place of ideas, the fittest survive.

But the phrase "survival of the fittest" harbors an important ambiguity. In competition, the *more* fit tend to prevail over the *less* fit, but this does not mean that either party is the *most* fit. Darwin's great insight was that evolution proceeds by incremental improvements which—if all else is stable—would eventually lead to performance optimality. In dynamically changing environments, however, all else is *not* stable and the process of incremental improvement is unending.

The practical implication of uncertainty, for designers and planners, is that the paradigm of performance-optimization is unreliable. This paradigm says: use the best model to find the design with the best possible performance. The trouble with this strategy is that, in situations of uncertainty, the best model is likely to err in important respects. The predictions of the best model are unreliable, especially predictions of rare or extreme events. This is true of all models, even probabilistic models. In situations where we must manage severe or extreme events, the tails of estimated probability distributions are likely to err substantially. This means that designs based on, for instance, predictions of 1 in a million, are subject to errors which we cannot accurately assess.

The practical implication of uncertainty is that we must ask: What outcomes are required? What performance is necessary? Engineers use this approach by asking: What is the design specification? This is different from asking: What is the best possible performance? For instance, we may require the failure probability of a critical infrastructure to be less than 1 in a million. This is different from minimizing the failure probability.

When we satisfy a design spec, we seek acceptable (and possibly very demanding) but sub-optimal performance. This usually means that many design options are predicted by our best models to satisfy

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the performance requirement. We can now choose the design which is most robust to uncertainty. This strategy is called *robust satisficing:* satisfy the requirements as robustly as possible, choose the design which satisfies the requirements over the largest range of deviation of reality from our current understanding.

In this talk we explain the info-gap theory of robust satisficing, describe its generic attributes, and illustrate its application to design of flood defense, financial risk management and other areas.

Selected References

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

• Yakov Ben-Haim, 2010, *Info-Gap Economics: An Operational Introduction,* Palgrave-Macmillan.

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