UHON 351U — Uncertainty

Spring 2013

Reasoning about any realistic domain always requires that some simplifications be made. The very act of preparing knowledge to support reasoning requires that we leave many facts unknown, unsaid, or crudely summarized. For example, if we choose to encode knowledge and behavior in rules such as "Birds fly" or "Smoke suggests fire," the rules will have many exceptions which we cannot afford to enumerate and conditions under which the rules apply (e.g., seeing a bird or smelling smoke) are usually ambiguously defined or difficult to satisfy precisely in real life. Reasoning with exceptions is like navigating a minefield: Most steps are safe, but some can be devastating.

— Judea Pearl, 1988

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Course Goals

What can we be sure of? How can we live in a world where we're sure of so little? How much does this uncertainty hold us back? Quantum mechanics and chaotic dynamics give some physical limits on our certainty; how much of this problem do they account for? How can we measure how sure we are? How can a computer deal with uncertainty? How can we use all of this to improve practical processes like medical decision making and business risk management?

Course Content

The primary learning objective is that students will integrally connect philosophical inquiry to quantitative and technological issues. An integral connection is evidenced by the ability to apply the philosophical issues to a choice of quantitative approaches to a practical problem.

Secondarily, students will acquire specific integrative competencies. They will be able to give philosophically meaningful and technically accurate descriptions of quantum uncertainty and chaos, to articulate the impact of philosophical issues (especially those around doubt, empiricism, confirmation, and induction) to practical problems not envisaged by the authors, and to choose and implement appropriate quantitative tools for modeling, measuring, and managing uncertainty in a practical problem.

A tertiary and supporting objective is that students will gain facility in systematic reading across technical and philosophical literature. Readings will be accessible to students, but different readings will be demanding in different ways.

List of Texts

1. M. Crouhy, D. Galai, and R. Mark, *The Essentials of Risk Management*, McGraw-Hill 2005
2. R. Descartes, *Meditations on First Philosophy*, any edition (free e-text available)
3. J. Faye, "Copenhagen Interpretation of Quantum Mechanics," *Stanford Encyclopedia of Philosophy*, `http://plato.stanford.edu/entries/qm-copenhagen/`, 2008
4. A. Fine, "The Einstein-Podolsky-Rosen Argument in Quantum Theory," *Stanford Encyclopedia of Philosophy*, `http://plato.stanford.edu/entries/qt-epr/`, 2009
5. A. X. Garg, et al., "Effects of Computerized Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes: A Systematic Review", *Journal of the American Medical Association* 293 (2005) pp. 1223–1238 (e-text available via SIU Library subscription).
6. J. Gleick, *Chaos*, Viking 1987
7. J. Halpern, *Reasoning About Uncertainty*, MIT Press, 2005

8. J. Hilgevoord and J. Uffink, "The Uncertainty Principle," *Stanford Encyclopedia of Philosophy*, `http://plato.stanford.edu/entries/qt-uncertainty/`, 2006
9. M. Huemer, "Quantum Mechanics for Philosophers," `http://home.sprynet.com/ owl1/qm.htm`, ca. 2003.
10. R. C. Jeffrey, *The Logic of Decision*, 2ed, U Chicago Press, 1983
11. K. Popper, *Logic of Scientific Discovery*, any edition
12. P. Szolovitz, R. S. Patil, and W. B. Schwartz, "Artificial Intelligence in Medical Diagnosis," *Annals of Internal Medicine* 108 (1988), pp. 80–87 (e-text available via SIU Library subscription).
13. L. Wittgenstein, *On Certainty*, any edition.

Course Activities

Two case studies will begin with the first discussions of the semester. One involves the design of software to aid practicing physicians in diagnosing and/or treating patients. The system should improve physician performance by making relevant recommendations, checking contraindications, or providing other consultant-like advice. The other case study involves constructing business financial and operating policies to ensure that a company takes appropriate advantage of selected risk opportunities, and mitigates risks not central to its business. In each case, some form of uncertainty is of paramount concern: in the first, the unknowns in the patient's condition and reaction to treatments; in the second, the external fortunes, financial and operational, that impact company performance.

The first major assignment will be due in week 5, and will assess the objective of accounting for chaos and quantum uncertainty. Students will write a paper addressing the question, "To what extent do physical limits on certainty account for uncertainty in our two case studies?"

The second major assignment will be due in week 10, and will address the goal of articulating philosophical ideas. Students will prepare a transcript of a fictional "Meet the Press" appearance of Karl Popper and Ludwig Wittgenstein, discussing the two case studies.

The third major assignment will be a team design project, and will constitute a summative assessment of the primary course objective. Each group of 3–5 students will select one of the two case studies, and will design a solution, in view of the scientific, philosophical, and mathematical apparatus explored in the course. Groups will present written and oral reports on their solutions, giving integrally connected scientific and philosophical justifications for their approaches. Teams may choose to submit a software artifact as a major component of their written report, but the basic expectation is only a concept-level design: that is, students should explain how the system would work.

We will meet on Tuesdays and Thursdays from 12:35 to 1:50. For each time, we will have some reading to discuss. The main point of each meeting will be to discuss your questions on the reading, in order to support your work on the major assignments. Of course, I will have plenty of questions to ask, as well, and will ask them of you, as time allows.

Having been a student once myself, I remember that it's helpful to have some graded work to make a nice calendar event for getting reading done on time. Consequently, for each week, you will turn in a summary of the reading for that week. These summaries will be due, unless otherwise announced, at the beginning of class on each Tuesday.

Approximate Timeline

Week 1 Introduction to the course; Case study in medical decision support. Readings: Garg, et al., Szolovitz, et al.

Week 2 Introduction to the course; Case studies in business risk and medical decision support. Readings: Crouhy, et al., Chapters 1–7

Week 3 Physical limits on certainty 1: Quantum Uncertainty; Readings: Huemer, Hilgevoord and Uffink, Fine, Faye

Week 4 Physical limits on certainty 2: Chaotic dynamics; Readings: Gleick, Chapters 1-5

Week 5 Universal Doubt; Readings: Descartes; Paper on physical contributions due

Week 6 Induction and Empiricism; Readings: Popper, Chapters I–IV

Week 7 Falsifiability and Testability; Readings: Popper, Chapters V–VII

Week 8 Interpretation of evidence; Readings: Popper, Chapters VIII–X

Week 9 Language and falsification; Readings: Wittgenstein, Aphorisms 1–299

Week 10 Communication and knowledge; Readings: Wittgenstein, Aphorisms 300-676

Week 11 Desire and certainty; Readings: Jeffrey, Chapters 1–3; Meet The Press due

Week 12 Quantifying desire: Jeffrey, Chapters 4–7

Week 13 Representing uncertainty; Readings: Halpern, Chapters 1–2

Week 14 In light of...; Readings: Halpern, Chapter 3

Week 15 Interdependence and expectation; Readings: Halpern, Chapters 4–5

Final Exam Week Final Project due

Grading

Grades will be calculated from the following sources:

Reading Summaries	100
Physical Limits Paper	100
Meet the Press	100
Design Project	200
	500pts

Failure to attend class regularly will certainly adversely affect your grades on each of these factors. For instance, while I do not artificially lower grades for bad attendance, it has consistently held that almost all grades below C- that have been achieved in classes that I have taught have been associated with significant attendance problems.

I will make the following guarantees about letter grades. I may decide to lower these criteria (i.e. give a higher grade than the one shown here, if I see that the questions were hard enough that lower numbers more accurately reflect my true standards), but will never raise them.

Percent of total	Grade
90–100	A
80–89	B
70–79	C
60–69	D
≤ 59	E

Prerequisites (And a Note on the Mathematical Level)

There are no formal prerequisites for the course. Students will feel most comfortable if they remember something of the probability they learned in school, but this is not strictly necessary. Nothing more than a level of curiosity and willingness to work is necessary as background for the course.

The course is designed in such a way that it is better off for everything you can bring to the table. Do you know some probability? Good, it will help. Some physics or philosophy? We'll be glad of it. Can you program? You'll be an asset to your group. Do you know something about business or medicine? Great. But don't feel too bad if you don't know these things. I bet you'll know something else that will turn out to be valuable.

Emergency Procedures

Southern Illinois University Carbondale is committed to providing a safe and healthy environment for study and work. Because some health and safety circumstances are beyond our control, we ask that you become familiar with the SIUC Emergency Response Plan and Building Emergency Response Team (BERT) program. Emergency response information is available on posters in buildings on campus, available on BERTs website at www.bert.siu.edu, Department of Safetys website www.dps.siu.edu (disaster drop down) and in Emergency Response Guideline pamphlet. Know how to respond to each type of emergency.

Instructors will provide guidance and direction to students in the classroom in the event of an emergency affecting your location. It is important that you follow these instructions and stay with your instructor during an evacuation or sheltering emergency. The Building Emergency Response Team will provide assistance to your instructor in evacuating the building or sheltering within the facility.