OR 681/SYST 573
Spring 2007
Decision Theory And Analysis

Instructor: Dave Schum

Course Description And Overview

This course concerns a variety of issues encountered in research on decision processes and the bearing of this research on the design of procedures and systems for assisting people as they perform decision tasks in the face of uncertainty. In many contexts such tasks involve difficult probabilistic inferences and equally difficult value or worth assessments. That people need, and frequently request, assistance in the performance of these tasks is no secret. What is at issue is the manner in which such assistance should be given and the various forms such assistance might take. Sensible recommendations for assisting people in decision and inference tasks require careful analyses of the tasks themselves as well as careful examination of the many judgments these tasks require. This course concerns research on inference and decision tasks themselves as well as on the judgmental requisites of these tasks. Many attempts to provide assistance in inference and decision tasks miscarry because of inadequacies in the manner in which the task is structured or because of innocence about the often-difficult judgmental requirements of these tasks. Research on methods for enhancing our inferential and decisional skills forms an important element in the Volgenau School Of Information Technology And Engineering, of which I am a member.

Before I tell you about the specific topics we will discuss in this seminar, I must make sure that you are aware of the essential objectives of this course so that you can make an informed choice about whether or not you wish to enroll in it or stay enrolled. A major objective of this course is to provide you with a careful and useful account of the essential ingredients of inference and decision tasks and how these ingredients might be combined. There is now a very substantial amount of research on a wide array of decision-related topics. This research occupies persons from many different disciplines. No single discipline contains a repository of all useful information about human inference and choice. Naturally, we can't cover all of this research in a single semester and so I have had to exercise some selectivity.

This is definitely not a vocationally oriented course. I make no claim that, as a result of taking this course, you will instantly be able to solve some decision-related problem you now face in your work or in your everyday activities. Such a claim would be very difficult for me to make since I have no present awareness of the particular decision problems you currently face. But what I will guarantee is that the topics we will cover in this course have direct relevance to inference and choice tasks regardless of the context in which they occur, including the ones of current interest to you. Be assured that in this course you will have ample opportunity to make us all aware of the particular decisions your present work may require. Students frequently complain that a course is too theory-oriented and offers no direct prescriptions for application. However, sensible application of some procedure or technique assumes that we understand the capabilities and limitations of these procedures. One major trouble is that people often make choices without being aware of all the ingredients these choices require. So, one of my major objectives in this course is to provide you with a thorough assessment of what ingredients are required in every choice made in the face of uncertainty.

As you notice, this course is cross-listed as Systems Engineering 573 and Operations Research 681. I welcome all of you and hope that I can provide a learning experience that is congenial to your interests regardless of what disciplinary affiliation you now have. Matters we will discuss in this course certainly cut across the areas just mentioned and many others as well. As I

proceed, I will try to provide specific examples of particular issues that arise in these disciplines. As I will mention again below, I will provide you with a number of assignments to test your mastery of the matters we discuss. As you will see, there are certain algorithms employed in the analysis of inference and choice. In other words, there is a computational element of these tasks. Some decision courses focus almost entirely on the application of these algorithms in particular situations. We will indeed examine some of these algorithms but my emphasis will be upon how these algorithms arise and on the consequences of employing them in various situations. Many of you have an interest in the topic of risk and its assessment and management. At various points in this course we will dwell on how risk is characterized and assessed by various means.

This course will concern, in roughly equal proportions, structural, probabilistic, and value-related elements of human choice. These elements are rarely, if ever, provided for us; they have to be discovered or generated by imaginative thought. To date there is no machine that can generate decision options and all their possible consequences and then assess the value of these consequences and determine how likely they are to occur. There are decidedly non-trivial measurement and judgmental issues that arise in human inference and choice, many of which we will discuss in this seminar. Inference and decision problems never spring forth in well-posed form; they have to be formulated or structured in the certain knowledge that such structures may have to be altered in light of new evidence and corrected or revised insights. Until quite recently, attention to the structural attributes of human inference and choice were overlooked in all but a small amount of scholarship. Also overlooked has been the role of imaginative reasoning in generating options and consequences, hypotheses or possibilities giving rise to these consequences, and valid evidentiary tests of these possibilities. The discovery of essential decision problem ingredients is of crucial importance and will command our special attention.

In our discussion of the probabilistic inferential elements of choice we will pay careful attention to the evidence upon which inferences are made and to alternative conceptions of the process of assessing and combining the "weight" or "force" of evidence in reaching a conclusion. This is quite an interesting time to be studying probabilistic reasoning. New systems of inference and probability have shed considerable light on some age-old problems associated with the task of drawing conclusions from incomplete, inconclusive, ambiguous, dissonant, and unreliable information. But there is still quite a bit of life left in conventional views of probability and inference when these views are expanded to incorporate the complex attributes of human inference observable in so many real life circumstances.

Our discussion of the value-related ingredients of human choice will focus upon the generation of options and their consequences as well as upon judgmental problems associated with placing a value on these consequences. In many situations, identified consequences have many attributes, some of which may be in conflict and that require us to consider various trade-offs we must make. Identification of consequence attributes and assessing their relative importance are usually not simple tasks. We will examine, in some detail, a variety of measurement issues that arise during the process of assessing human preferences. Study of the relation of these measurement issues to other forms of behavioral measurement is quite instructive. Of obvious concern to us is consideration of the various strategies that exist for combining our uncertainties and values in making a choice. Although there is no uncontroversial strategy for combining assessments of probabilities and values, there are some that prove very useful in many situations.

The word *rationality* is very commonly used with reference to the evaluation of human inference and choice. We frequently hear someone say that another person's inference or choice was not a "rational" one. The term "rationality" slips off the tongue rather easily, especially in connection with the inferences and choices made by others. However, just what constitutes a "rational" inference or choice is far from being settled. Indeed, what rationality means is just one among many controversial topics we will consider. In spite of this controversy about what

rationality means, there is some well-publicized behavioral research being used in support of the claim that we are all deficient in our basic inferential and decisional capabilities. In other words, the claim is made that we are all frequently irrational. Taken seriously, this research generates little confidence in the many societal institutions and organizations whose activities rest upon human inferences and decisions. But there are other views about the suitability of such research that offer a more charitable assessment of our basic intellectual competence. We will have a brief look at both sides of this current controversy.

Outline Of Major Topics

[Extensive Notes provided on each of these topics]

Section I: Preliminaries.

A. Essential Ingredients Of Human Inference And Choice.
B. On The Adequacy Of Decisions: What Constitutes "Rational" Inference and Choice?
C. Normative-Descriptive Issues.
D. Judgment and Measurement Issues.
E. Some Examples of Choice Paradigms.
F. Decision Analysis: Divide and Conquer

Section II: On the Imaginative and Structural Elements of Inference and Choice

A. Three Forms Of Reasoning To Consider.
B. Probabilistic Reasoning and the Construction of Inference Networks
C. Decision Structuring: Decision Trees and Influence Diagrams

Section III: Evidence and Probabilistic Reasoning.

A. On the Credentials of Evidence: Relevance, Credibility, and Inferential Weight or Force.
B. Logically-Distinguishable Forms And Types Of Evidence.
C. Alternative Views Of Probabilistic Judgment and Reasoning.
D. A Survey Of Evidential And Inferential Subtleties.
E. Probabilistic Reasoning and the Science of Complexity

Section IV: Decision Consequences and Values.

A. Value-Utility: A Brief Historical Summary.
B. Basic Formal Issues In The Assessment Of Value/Utility.
C. Single-Attribute Utility: Concepts And Assessment Methods.
D. Multiattribute Utility Assessment.

Reading Materials

As I noted, no single discipline can lay claim to all the matters of interest in this course. I now extend this idea even farther. No single instructor can tell you all there is to be said about the complexities of human inference and choice; neither can any single textbook. Human inference and choice draw upon intellectual processes of the highest order. Consequently, those who study these processes soon learn to take all the help they can get, from wherever it comes. Textbooks come and go. For several years I have used two books [both paperback] that were quite well accepted by students enrolled in this course. Unfortunately, they are both now out of print. So, I have had to decide on another book for this course. The one I have chosen is:

Clemen, Robert T. *Making Hard Decisions: An Introduction to Decision Analysis*. Duxbury Press, Belmont, CA 1996 [2nd edition].

Why would I ask you to read a book for which there are later editions? You may be aware of the fact that in the state of Virginia, legislators have exhibited great concern over the costs to students of the textbooks they are required to purchase for their courses. You all have great experience in such matters. The cost of textbooks is larcenous as we all know. Instructors are now required to adopt older versions of textbooks, if they are available, and for which there are likely to be used copies. The later editions of the Clemen book are certainly more attractive and come with a CD. But they do not cover essential matters any better than the older version I have asked you to ourchase.

The edition of the Clemen book I have asked you to purchase has been well received and covers many topics in decision analysis. It is a long book and I will not ask you to read all of it. Particular assignments from this book appear below. I will try my best to make our discussions in class correspond with the order in which topics are discussed in this book. This is not always easy to do since I will tell you about many things Clemen does not mention in his book. If all I told you in class was also said in this book, you should complain very loudly to my Departmental Chairperson or to my Dean. On some topics, you will find your instructor in disagreement with what your author says. I cannot possibly overemphasize how controversial are many essential topics in human inference and choice. Many matters we discuss will continue to be subjects for debate and discourse for a very long time.

In addition to Clemen's book, I will regularly provide you with extensive notes and handouts on all matters we discuss in class. I will have these notes for you in advance of the time they are to be discussed in class so that you can think about these matters and challenge me about what I have told you. You cannot challenge Clemen, but you can certainly challenge me each time we meet in class. The discussions we have in class are most important. Be assured that in class I will not simply go over the notes I have given you in advance. In a few cases this will be necessary because of the nature of the topic or the particular notes I will give you. The notes I give you simply form a major vehicle for getting our discourse started during each class. You can provide other vehicles by raising particular decision problems you now face in your work or that are currently being faced by persons in various governmental military, business, or other organizations. In short, my major objective in class will be to draw ideas out of you. I am a scholar, not a preacher, and so you should not expect to hear me say that the ideas I will mention concerning inference and choice have been settled for all time. Your own ideas and the experiences upon which they are based are so important. I will do all I can to create an atmosphere in class that makes you willing to share your ideas and experiences with others in the class.

Reading Assignments

These reading assignments are keyed to the outline of topics given above. Notice that I have not assigned all the chapters and have assigned only parts of others.

Section I: Chapters 1 and 2, pages 1-40.

Section II: Chapter 3, pages 41 - 90,
Chapter 4, pages 101-116; 118-35
Chapter 6, pages 187-215

Section III: Chapter 7, pages 219-264 [optional if you have had a recent course in probability]
Chapter 8, pages 265-298

Section IV: Chapter 13, pages 461-497
Chapter 14, pages 503-526
Chapter 15, pages 530-561

Method Of Evaluation

Your grade in this course will depend upon two methods of evaluation: a paper and some assigned exercises. As you will observe as we proceed, we will cover a fair number of different issues and problems in the study and analysis of decision tasks. In short, the breadth of coverage of decision-related topics in this seminar will be substantial. You should naturally be inclined to ask the question: where does depth of coverage come in? The answer to this question depends upon you and your interests. It is natural to expect that you will find at least one topic that captures your interest or that is especially relevant to the work you may now be doing. Here is where depth comes in: on the topic you choose to examine in as much detail as your interest and time allows. Naturally, I will be prepared to help you find as much information as I can about this topic.

60% of your grade in this course will be based upon a paper you write or project you perform (and describe) on some topic of your choice, provided that this topic bears directly upon human inference or choice. This paper must be an original work; i.e., papers written to satisfy requirements of other courses are not acceptable. You have every right to know what I expect of your papers or projects. The first thing I will tell you is that if you are interested in your chosen topic and have examined it carefully, the odds are strong that I will enjoy reading what you have to say about it. As Samuel Johnson once remarked: "What is written without interest is, in general, read without pleasure". As you work on your paper or project, remember that you do this mainly for yourself. Students frequently ask me: what do you want in this paper? The appropriate question is: what do you [the student] want? My major objective in this assignment is to give you the opportunity to satisfy your own curiosity about some decision-related matter that captures your interests and about which you wish to have some greater depth of understanding. I will of course be very pleased to discuss with you ideas you may have for papers you could write or projects you could perform.

In the 20 years I have offered this course at GMU I have received papers on many different topics. Here is a brief listing of some of the general themes of papers I have found quite interesting and enjoyable to read.

1) An analysis of some past, current, or future decision you and perhaps others face in the work you now do in a business, military, or other governmental context. It would be quite appropriate for you to apply what you have learned in this course to these kinds of decisions. There is one caution here that I mention on the basis of considerable prior experience with papers/projects of this sort. In some instances a person will spend the entire paper describing the particular institutional context in which decisions are required and end up saying little or nothing about how these decisions could be formulated and analyzed using any methods discussed in class or in the text I have assigned. The result is that I am left completely in the dark about how much this person has learned in this course. An additional problem I face is that, being usually innocent of the particular details of the contexts in which you presently find yourself, I have very little basis for evaluating what you have done. The moral here is quite simple. If you choose to present an analysis of some current job-related decision problem, make sure that you relate it to one or more concepts or methods that have been of concern in this seminar.

2) An analysis in greater depth of some particular inference or decision topic that has captured your interest in this seminar.

3) As a result of your reading or our discussions in class, you may wish to criticize current positions taken on a particular issue either by your instructor or by other persons who have written on the topic. As I have noted, very little about human inference and choice is regarded as fixed for all time. As we proceed in this seminar, you will find many topics about which there is unending controversy. Where there is controversy, there is usually a graduate paper lurking. Your ideas about the matters at issue may be every bit as valuable as those that now exist.

4) An analysis of some past, current, or future choice you face in your personal life. People face decisions all the time concerning employment opportunities, purchases, and many other matters. It would be quite appropriate to employ the concepts and methods of analysis we discuss to personal decisions you now face or have faced in the past.

These are just some of the general topic areas that might get you started thinking about your paper or project. There are other options of course. The final matter here concerns grades I assign to papers or projects. Most students have more than a passing interest in what grading standards a professor has in the back of her/his mind as far as assignments, such as I have described, are concerned. Here, very generally, are some characteristics of what I regard as A, B, and C papers/projects.

Grade of C: A graduate paper should get a grade of C if it reads essentially like a high school book report. In some cases a student's paper reads like: " X says this, Y says, this, and Z says that". In such an effort there has been no attempt by the student to be critical of what X, Y, and Z said, nor has there been any attempt to integrate what these persons have said in any meaningful or useful manner. A report of a project or an analysis also gets a grade of C if I cannot find any connection in the paper to any decision or inference concept or analytic method we have discussed in this course.

Grade of B: A critical and well-integrated analysis of what others have done and said gets a grade of B on a graduate paper. Similarly, a report of a project in some ongoing context gets a grade of B if there is at least some attempt to relate it to the essential topics in this seminar.

Grade of A: If your analysis of some topic is both critical and well-integrated and, in addition, if you have provided your own thoughts about this matter in a defensible way, this paper begins to look like an A paper. In graduate work what counts most is the application of your own imaginative reasoning and critical thought to the task at hand. The same idea extends to papers/projects on specific analyses of decisions you encounter in your jobs or elsewhere. In short, what **YOU** think about the matters of concern to you counts the most and is something on which all of us who teach graduate courses place the highest value.

The remaining 40% of your grade will be based on four assignments I will give you. Some of these assignments will be problems for you to solve. Others will require your critical and imaginative thought about a decisional or inferential issue in some situation. Some will come from your text.

I would greatly appreciate receiving your paper and other assignments in hard copy rather than in electronic form. I would much rather spend the time reading your work carefully, and providing you with comments, than waiting to download and print your work.

Where To Find Your Instructor.

I hope you will feel free to call upon me at any time; do not hesitate to call me at home if you can't find me at the office. I am a member of the full-time faculty at GMU. What this means is that you can get all the help you need from me, when you need it. I can usually be found at one of the following locations:

Office: Room 111-A, Science & Technology Bldg II. GMU Phone: 703-993-1694
Home: 2219 Chestertown Dr., Vienna, Va. Phone: 703-698-9515
e-mail: Please use my home e-mail which is: <dschum398@earthlink.net>

I do hope you enjoy this course and I will do all I can to help make this a valuable experience for you.