INFT 803 - Complex Adaptive Systems, Knowledge, and Systems Management (3:3:0) Complexity theory is an emerging field of study that is evolving from several major knowledge areas: mathematics, physics, biology, economics, organizational science, computational intelligence and systems engineering. It is a needed set of endeavors brought about by two realities. The first is that modern science often does not reflect all of reality, but only the part of reality that is ordered, linear, ergodic, isolatable, predictable, observable, and controllable. The second reality is that modern trends toward disciplinary specialization run counter to the major need for knowledge integration and transdisciplinarity for resolution of contemporary issues. Fundamentally, a system is complex when we cannot understand it through simple cause-and-effect relationships or other standard methods of systems analysis. In a complex system, we cannot reduce the interplay of individual elements to the study of those individual elements considered in isolation. Often, several different models of the complete system, each at a different level of abstraction, are needed. There are several *sciences of complexity*, and they generally deal with approaches to understanding the dynamic behavior of units that range from individual organisms to the largest economic, technical, social, and political organizations. Many of these studies are agent or element based and involve complex adaptive systems and hierarchical systems. The structure and behavior of these complex systems is not dictated uniquely by the edicts of a leader, but emerges and evolves in a natural manner through the interactions of the agents. One measure of system complexity may be the complexity of the simulation model necessary to effectively predict system behavior. The more the simulation model must look like the actual system to yield the same behavior, the more complex the system. As a general rule, we cannot create models that will accurately predict the outcomes of complex systems. We can, however, create a model that will accurately simulate the *processes* the system will use to create a given output. This awareness has profound impacts for economic, organizational, and many other efforts that are concerned with systems of systems that are also of large scale and scope. Most studies of complex systems often run completely counter to the trend toward increasing fragmentation, compartmentalization, and specialization in most academic disciplines. The current trend in complexity studies is to reintegrate the fragmented interests of disciplines into a common pathway. Without a cohesive systems ecology to guide the use of information and associated knowledge, and without the necessary knowledge integration, the engineering and management of complex systems is unlikely.

The course will first provide an overview of complexity theory. There will be three principal specialty areas discussed in the course, such that the course itself is comprised of four parts.

1. **Overview of Agent Based Complexity and Associated Simulation and Modeling**. We will provide a general wide-scope overview of complex adaptive systems**,** generally based upon Kelly (1994) and Holland (1995, 1998): and with some specific focus on the ecological and organizational overview of Kauffman (1995). The ecological focus is of particular interest as there is a great deal of contemporary interest in adapting ecological thought processes to the development of models for information, knowledge, and systems management. We will briefly study the recent work by Casti (1997) in modeling and simulation, and will pay particular attention to cellular automata simulation models, nonlinear dynamics, mathematical biology, and agent based models with application to the social and organizational sciences (Epstein 1997; Epstein and Axtell, 1996; Gilbert and Troitzsch, 1999).
2. **Non-Zero Sum Games, Conflict Resolution and Agent Based Evolutionary Models of Cooperation and Competition**. Our efforts here will generally be based on the work of Axelrod (1997) and a general background in non-zero sum evolutionary games (Samuelson, 1997) will be provided and used to study a number of interesting and relevant problems such as the prisoner's dilemma and the tragedy of the commons.
3. **Increasing Returns to Scale, Network Effects, Path Dependence in the Economy, and Evolutionary Economics**. Our efforts here will examine contemporary studies concerning the economy as a complex system (Arthur, 1994; Arthur, Durlauf, and Lane, 1997), and the related area of evolutionary economics (Andersen, 1996), with application to such real issues as the Microsoft Internet Explorer and system of systems integration at the level of product, process, and organization. We will discuss the excellent work of Shapiro and Varian (1999) and other works concerning the network economy. We will also discuss the emergence of the Internet as a complex adaptive system and provide some general guidelines here, and in the next part for systems management of such systems.
4. There is much current interest in such subjects as complexity and creativity, uncertainty, information imperfection, and nonlinear dynamics, and learning in organizations. **Knowledge Management** is a term describing management of the environment for knowledge transfer such that the transition from data to information to knowledge is efficient and effective (Wilson and Bramer, 1994; Ruggles, 1997; Albert and Bradley, 1997; Davenport and Prusak, 2000; Brown and Duguid, 2000; von Krogh, Ichijo, and Nonaka, 2000). In the concluding lectures, we describe recent work in this area and likely futures for knowledge management, and systems and organizational management (Axelrod and Cohen, 1999; Kelly and Allison, 1999) through the use of the principles of complex adaptive systems.

There will be extensive use of the Internet as a knowledge acquisition tool. Students in the class will be asked to share experiences concerning application areas for the subjects discussed. Even though it may appear that there are many topics covered, there are quite a number that are not covered. Hopefully, the course will provide the background for additional readings, study, and research in these areas.

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Course Call Number 05781, Fall 2001, Thursday from 7:20 PM to 10:00 PM in Thompson 108.

References: Much additional literature, and some simulation models, will be obtained from the Internet. Several new books will likely emerge during the semester, and an overview of these may be provided.

Arthur, W. Brian W., Durlauf, Steven N., and Lane, David A. (Eds.), *The Economy as an Evolving Complex System II*, Addison Wesley, Reading MA, 1997.

Arthur, W. Brian, *Increasing Returns and Path Dependence in the Economy*, University of Michigan Press, Ann Arbor MI, 1994.

Axelrod, Robert, *The Complexity of Cooperation: Agent-Based Models of Competition and Cooperation*, Princeton University Press, Princeton NJ, 1997.

Axelrod, Robert, and Cohen, Michael D., *Harnessing Complexity: Organizational Implications of a Scientific Frontier*, Free Press, New York, 1999.

Brown, John Seeley, and Duguid, *The Social Life of Information,* Harvard Business School Press, NY, 2000.

Casti, John, *Would-be Worlds: How Simulation Is Changing the Frontiers of Science*, John Wiley, New York NY, 1997.

Davenport, Thomas H. and Prusak, Laurence*, Working Knowledge: How Organizations Manage What They Know*, Harvard Business School Press, Boston MA, 2000.

Epstein, Joshua M. and Axtell, Robert, *Growing Artificial Societies: Social Science from the Bottom Up*, MIT Press, Cambridge MA, 1996.

Epstein, Joshua M., *Nonlinear Dynamics, Mathematical Biology, and Social Science*, Addison Wesley, Reading MA, 1997.

Gilbert, N., and Troitzsch, K. G., *Simulation for the Social Scientist*, Open Univ. Press, Buckingham UK, 1999.

Holland, John N., *Hidden Order: How Adaptation Builds Complexity*, Addison Wesley, Reading MA, 1995.

Holland, John N., *Emergence: From Chaos to Order*, Addison Wesley, Reading MA, 1998.

Kauffman, Stuart*, At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*, Oxford University Press, New York NY, 1995.

Kelly, Kevin, *Out of Control: The New Biology of Machines, Social Systems, and the Economic World*, Addison Wesley Publishers, Reading MA, 1994.

Kelly, Susanne, and Allison, Mary Ann, *The Complexity Advantage: How the Science of Complexity Can Help Your Business Achieve Peak Performance*, McGraw Hill Book Co., New York, 1999.

Samuelson, Larry, *Evolutionary Games and Equilibrium Selection*, MIT Press, Cambridge MA, 1997.

Shapiro, C. and Varian, H. R., *Network Rules: A Strategic Guide to the Network Economy*, Harvard Business School Press, Boston MA, 1999.

Stacey, R. D., Griffin, D., and Shaaw, P., *Complexity and Management*, Routledge, London, 2000.

Von Krogh, G., Ichijo, K., and Nonaka, I., *Enabling Knowledge Creation: How to Unlock the Mystery of Tacit Knowledge and Release the Power of Innovation*, Oxford University Press, New York, 2000.

Grades will be determined as follows: 50% - exams, 20% - project presentation, 30% - home assignments. Two take home exams will be given, one at the middle of the semester and one at the end of the semester. There will be a project on complexity, including a written report and oral presentation. Prerequisites: microeconomics, differential equations, probability, insanity, game theory, variational calculus or APS consent.

INFT 803 - Syllabus (subject to change) - Fall 2001

1. Part 1 - Overview: 30 August, 6, 13 September
2. Part 2 - 20, 27 September, 4 October
3. Take home Mid Term Exam Due 18 October
4. Part 3 - 18, 25 October, 1 November
5. Part 4 - 8, 15, 29 November
6. Term Paper Presentations 6 December
7. Take Home Final Exam Due 13 December

APS 6 August 2001