Intelligent Systems, Introduction to

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The term “intelligent systems” has come to mean many different things in many different contexts and, like most things related to complex systems, it is hard to nail down a specific definition that is both rigorous enough to discriminate out those things which should not be included but is loose enough to include those that are. As in defining terms like “agents” or “robots,” one is able to find overly inclusive definitions, such as “an autonomously acting entity” where a thermostat in the latter case, or hard disk controller in the former, would meet the definition. On the other hand, tighten up the definition and telerobotics or Google’s search bots no longer fit, despite being clearly related technologically. In the case of intelligent systems, too tight a definition of intelligence removes, say, the behaviors we see in a dog, which can seek out a prey or be trained to beg for its dinner, but loosen the definition and we find ourselves talking about systems with the intelligence of a clam.

In this chapter, we are holding primarily to a tighter definition and starting to look at some of the kinds of behaviors that take us into areas traditionally associated with human intelligence. While several of the sections of this book deal with areas associated with, loosely defined, intelligent behaviors and others look specifically at aspects of artificial intelligence tied closely to data or a model, in this short section we pick up some of the missing pieces that help us complete the puzzle. The small number of papers in this section should not cause one to believe that there is little relation between intelligent systems and complexity but rather that other sections of this encyclopedia necessarily included aspects of intelligence defined at some level – controlling against complexity demands it. The reader looking for other entries on artificial intelligence and complex systems will find them in many sections of this volume, particularly including those on:

► Agent Based Modeling and Simulation
► Complexity and Non-linearity in Autonomous Robotics, Introduction to
► Data-Mining and Knowledge Discovery, Introduction to
► Data-Mining and Knowledge Discovery, Neural Networks in
► Data-Mining and Knowledge Discovery: Case-Based Reasoning, Nearest Neighbor and Rough Sets
► Soft Computing, Introduction to
► Nonsmooth Analysis in Systems and Control Theory
► Chronological Calculus in Systems and Control Theory

However, despite the strong ties between these many subareas, there were some aspects of intelligent systems left out of these other topic areas, and this section is provided to cover these. One such example is that of the use of mobile agents as the basis for intelligent cooperation among systems (see “► Mobile Agents”). The primary need for mobility is in bandwidth-limited communications, and with the growth of modern computer networks, the area has gotten less attention of late. However, with the growing need for, and use of, sensor networks, wireless networks in noisy environments, deep-sea or space robotics, and other bandwidth-limited systems, agent-based

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modeling and simulation techniques can be used to model the networks, but not run on the networks themselves. Thus, an adaptive network that needs to do agent-to-agent communication for self-tuning will be seriously impacted in a bandwidth-limited environment. Mobility can be used to help in such situations, moving small amounts of code to where the data it manipulates is stored, rather than moving the large amounts of data to where the computation could be run. Using such mobile agents bring both new capabilities, and new challenges, and as we try to increase the intelligence of systems operating in networks with disconnection, low bandwidth, or high latency, such as many of the networks deployed in warfighting situations, agent mobility is regaining attention as an important area of research.

Another area that needs to be covered is that of the role of intelligent systems in the modeling and simulation area (see “Artificial Intelligence in Modeling and Simulation”). While agent-based modeling, as discussed elsewhere in this encyclopedia, is an important area, there are aspects of modeling it does not fully cover. One of these is the use of symbolic reasoning for use in validating models and simulation. Another is the actual modeling of the reasoning of other agents. For example, a baseball player recovering a ball that dropped in the outfield must be able to reason about what the base runners, who are trying to move up, and his teammates, who are trying to hold them back, will most likely do. The player’s skill in guessing the behaviors of these other agents, both competitive and cooperative, could be the difference between whether the game is won or lost.

As well as improving our capabilities in modeling and simulating systems, it is important to look at how, with the use of intelligent systems, we might better control the complex systems being modeled. Instead of trying to model a complex plant directly, in this section we look at work that takes a different approach. Instead we consider the knowledge-based control that results from observing, studying, and understanding the behavior of a plant and/or the behavior of a human controlling it (see “Intelligent Control”). This area includes looking at soft-computing approaches to create an “approximate reasoning” solution that can be used for mimicking the control decisions that would be made by a human monitoring a plant, rather than for modeling the plant itself. Fuzzy logic, a particular branch of soft control has been successfully applied to the control of many complex systems, a number of which are described here. (The reader with a sense of humor may see a certain irony in many manufacturers’ use of fuzzy logic to improve the picture on their camcorders and television sets, but let us leave that unexplored.) Of particular import, this entry outlines various ways in which the mathematical operations used in such control can be combined, allowing for the control of complex, nonlinear systems that defy simpler control regimes.

Looking at very complex situations, a human operator, or at least a program simulating one, may want to look beyond soft computing and deal with the world at a higher level. One of the key abilities which separates the human from other primates and animals is our ability to learn over time to abstract away many details of the complex world in which we live and to make plans for how to control it over time. Where planning itself can be a complex problem-solving task, learning how to abstract key aspects of situations and to apply plans to these is a critical need for dealing with complexity (see “Learning and Planning (Intelligent Systems)”). Exploring how we learn to plan is an area which has been gaining importance in the intelligent systems area as approaches which do not learn, but which apply brute force problem solving to larger and larger problems, are reaching the limits of their capabilities against the increasingly complex domains in which we wish to deploy our computational systems.

A recurring theme that arises in all of these attempts to provide intelligent behavior in evermore-complex systems environments is that of using a level of abstraction to reason not about some data or system itself, but about the meaning of the behaviors being observed. A critical aspect of performing such abstraction is the ability to represent a model of a system to the computer in a machine-readable
way. The term “ontology” is used to describe this computer-based representation of the domain in which a system is trying to function.

Although ontologies have been around for a long time in AI, they have recently come back into their own in trying to help computer systems interact with one of the most complex human constructions in history – the millions of billions of dynamically changing bits of information that comprise the World Wide Web. While the Web has changed a great many aspects of our society, understanding its dynamics remains a major challenge (see Berners-Lee et al. 2006). The use of ontologies, and other AI techniques, to help computers better process this massive information space is the raison d’être of the “Semantic Web,” an overview of which is also presented in this section (see “Semantic Web”).

In short, this section, despite its brevity, picks up a number of themes that arise throughout this encyclopedia. These five entries will help the reader understand how many of the themes above are connected together via the use of technologies developed in artificial intelligence labs, allowing the creation of intelligent systems that provide a key tool in our arsenal for dealing with the complexity of the natural world and/or the complex human society that has evolved to let us live in it.

**Bibliography**