"Getting Started" Guide to Cybernetics

What does the word "cybernetics" mean?

"Cybernetics" comes from a Greek word meaning "the art of steering".

Cybernetics is about having a goal and taking action to achieve that goal.

Knowing whether you have reached your goal (or at least are getting closer to it) requires "feedback",
a concept that comes from cybernetics.

From the Greek, "cybernetics" evolved into Latin as "governor". Draw your own conclusions.

When did cybernetics begin?

Cybernetics as a process operating in nature has been around for a long time.

Cybernetics as a concept in society has been around at least since Plato used it to refer to government.

In modern times, the term became widespread because Norbert Wiener wrote a book called "Cybernetics" in 1948. His sub-title was "control and communication in the animal and machine". This was important because it connects control (a.k.a., actions taken in *hope* of achieving goals) with communication (a.k.a., connection and information flow between the actor and the environment). So, Wiener is pointing out that effective action requires communication.

Wiener's sub-title also states that both animals (biological systems) and machines (non-biological or "artificial" systems) can operate according to cybernetic principles. This was an explicit recognition that both living and non-living systems can have *purpose.* A scary idea in 1948.

What's the connection between "cybernetics" and "cyberspace"?

According to the author William Gibson, who coined the term "cyberspace" in 1982:

“Cyber” is from the Greek word for navigator. Norbert Wiener coined “cybernetics” around 1948 to denote the study of “teleological mechanisms” [systems that embody goals]. — *NY Times Sunday Magazine 2007*

Artificial Intelligence and cybernetics: Aren't they the same thing?

No way. Keep reading below. Amaze your friends.

This content was written for an encyclopedia and the early paragraphs explain foundational concepts. You can always skip down links at page bottom if you want to see videos or read more about what cyberspace has to say about cybernetics.

CYBERNETICS — A Definition

Artificial Intelligence and cybernetics: Aren't they the same thing? Or, isn't one about computers and the other about robots? The answer to these questions is emphatically, No.

Researchers in Artificial Intelligence (AI) use computer technology to build intelligent machines; they consider implementation (that is, working examples) as the most important result. Practitioners of cybernetics use models of organizations, feedback, goals, and conversation to understand the capacity and limits of any system (technological, biological, or social); they consider powerful descriptions as the most important result.

The field of AI first flourished in the 1960s as the concept of universal computation [Minsky 1967], the cultural view of the brain as a computer, and the availability of digital computing machines came together to paint a future where computers were at least as smart as humans. The field of cybernetics came into being in the late 1940s when concepts of information, feedback, and regulation [Wiener 1948] were generalized from specific applications in engineering to systems in general, including systems of living organisms, abstract intelligent processes, and language.

Origins of "cybernetics"

The term itself began its rise to popularity in 1947 when Norbert Wiener used it to name a discipline apart from, but touching upon, such established disciplines as electrical engineering, mathematics, biology, neurophysiology, anthropology, and psychology. Wiener, Arturo Rosenblueth, and Julian Bigelow needed a name for their new discipline, and they adapted a Greek word meaning "the art of steering" to evoke the rich interaction of goals, predictions, actions, feedback, and response in systems of all kinds (the term "governor" derives from the same root) [Wiener 1948]. Early applications in the control of physical systems (aiming artillery, designing electrical circuits, and maneuvering simple robots) clarified the fundamental roles of these concepts in engineering; but the relevance to social systems and the softer sciences was also clear from the start. Many researchers from the 1940s through 1960 worked solidly within the tradition of cybernetics without necessarily using the term, some likely (R. Buckminster Fuller) but many less obviously (Gregory Bateson, Margaret Mead).

Limits to knowing

In working to derive functional models common to all systems, early cybernetic researchers quickly realized that their "science of observed systems" cannot be divorced from "a science of observing systems" — because it is we who observe [von Foerster 1974]. The cybernetic approach is centrally concerned with this unavoidable limitation of what we can know: our own subjectivity. In this way cybernetics is aptly called "applied epistemology". At minimum, its utility is the production of useful descriptions, and, specifically, descriptions that include the observer in the description. The shift of interest in cybernetics from "observed systems" — physical systems such as thermostats or complex auto-pilots — to "observing systems" — language-oriented systems such as science or social systems — explicitly incorporates the observer into the description, while maintaining a foundation in feedback, goals, and information. It applies the cybernetic frame to the process of cybernetics itself. This shift is often characterized as a transition from 'first-order cybernetics' to 'second-order cybernetics. Cybernetic descriptions of psychology, language, arts, performance, or intelligence (to name a few) may be quite different from more conventional, hard "scientific" views — although cybernetics can be rigorous too. Implementation may then follow in software and/or hardware, or in the design of social, managerial, and other classes of interpersonal systems.

Origins of AI in cybernetics

Ironically but logically, AI and cybernetics have each gone in and out of fashion and influence in the search for machine intelligence. Cybernetics started in advance of AI, but AI dominated between 1960 and 1985, when repeated failures to achieve its claim of building "intelligent machines" finally caught up with it. These difficulties in AI led to renewed search for solutions that mirror prior approaches of cybernetics. Warren McCulloch and Walter Pitts were the first to propose a synthesis of neurophysiology and logic that tied the capabilities of brains to the limits of Turing computability [McCulloch & Pitts 1965]. The euphoria that followed spawned the field of AI [Lettvin 1989] along with early work on computation in neural nets, or, as then called, perceptrons. However the fashion of symbolic computing rose to squelch perceptron research in the 1960s, followed by its resurgence in the late 1980s. However this is not to say that current fashion in neural nets is a return to where cybernetics has been. Much of the modern work in neural nets rests in the philosophical tradition of AI and not that of cybernetics.

Philosophy of cybernetics

AI is predicated on the presumption that knowledge is a commodity that can be stored inside of a machine, and that the application of such stored knowledge to the real world constitutes intelligence [Minsky 1968]. Only within such a "realist" view of the world can, for example, semantic networks and rule-based expert systems appear to be a route to intelligent machines. Cybernetics in contrast has evolved from a "constructivist" view of the world [von Glasersfeld 1987] where objectivity derives from shared agreement about meaning, and where information (or intelligence for that matter) is an attribute of an interaction rather than a commodity stored in a computer [Winograd & Flores 1986]. These differences are not merely semantic in character, but rather determine fundamentally the source and direction of research performed from a cybernetic, versus an AI, stance.

Underlying philosophical differences between AI and cybernetics are displayed by showing how they each construe the terms in the central column. For example, the concept of "representation" is understood quite differently in the two fields. Relations on the left are causal arrows and reflect the reductionist reasoning inherent in AI's "realist" perspective that via our nervous systems we discover the-world-as-it-is.

> Relations on the right are non-hierarchical and circular to reflect a "constructivist" perspective, where the world is invented (in contrast to being discovered) by an intelligence acting in a social tradition and creating shared meaning via hermeneutic (circular, self-defining) processes. The implications of these differences are very great and touch on recent efforts to reproduce the brain [Hawkins 2004, IBM/EPFL 2004] which maintain roots in the paradigm of "brain as computer". These approaches hold the same limitations of digital symbolic computing and are neither likely to explain, nor to reproduce, the functioning of the nervous system.

Influences

Winograd and Flores credit the influence of Humberto Maturana, a biologist who recasts the concepts of "language" and "living system" with a cybernetic eye [Maturana & Varela 1988], in shifting their opinions away from the AI perspective. They quote Maturana: "Learning is not a process of accumulation of representations of the environment; it is a continuous process of transformation of behavior through continuous change in the capacity of the nervous system to synthesize it. Recall does not depend on the indefinite retention of a structural invariant that represents an entity (an idea, image or symbol), but on the functional ability of the system to create, when certain recurrent demands are given, a behavior that satisfies the recurrent demands or that the observer would class as a reenacting of a previous one." [Maturana 1980] Cybernetics has directly affected software for intelligent training, knowledge representation, cognitive modeling, computer-supported coöperative work, and neural modeling. Useful results have been demonstrated in all these areas. Like AI, however, cybernetics has not produced recognizable solutions to the machine intelligence problem, not at least for domains considered complex in the metrics of symbolic processing. Many beguiling artifacts have been produced with an appeal more familiar in an entertainment medium or to organic life than a piece of software [Pask 1971]. Meantime, in a repetition of history in the 1950s, the influence of cybernetics is felt throughout the hard and soft sciences, as well as in AI. This time however it is cybernetics' epistemological stance — that all human knowing is constrained by our perceptions and our beliefs, and hence is subjective — that is its contribution to these fields. We must continue to wait to see if cybernetics leads to breakthroughs in the construction of intelligent artifacts of the complexity of a nervous system, or a brain.

Cybernetics Today

The term "cybernetics" has been widely misunderstood, perhaps for two broad reasons. First, its identity and boundary are difficult to grasp. The nature of its concepts and the breadth of its applications, as described above, make it difficult for non-practitioners to form a clear concept of cybernetics. This holds even for professionals of all sorts, as cybernetics never became a popular discipline in its own right; rather, its concepts and viewpoints seeped into many other disciplines, from sociology and psychology to design methods and post-modern thought. Second, the advent of the prefix "cyb" or "cyber" as a referent to either robots ("cyborgs") or the Internet ("cyberspace") further diluted its meaning, to the point of serious confusion to everyone except the small number of cybernetic experts.

However, the concepts and origins of cybernetics have become of greater interest recently, especially since around the year 2000. Lack of success by AI to create intelligent machines has increased curiosity toward alternative views of what a brain does [Ashby 1960] and alternative views of the biology of cognition [Maturana 1970]. There is growing recognition of the value of a "science of subjectivity" that encompasses both objective and subjective interactions, including conversation [Pask 1976]. Designers are rediscovering the influence of cybernetics on the tradition of 20th-century design methods, and the need for rigorous models of goals, interaction, and system limitations for the successful development of complex products and services, such as those delivered via today's software networks. And, as in any social cycle, students of history reach back with minds more open than was possible at the inception of cybernetics, to reinterpret the meaning and contribution of a previous era.

Such a short summary as this cannot represent the range and depth of cybernetics, and the reader is encouraged to do further research on the topic. There is good material, though sometimes not authoritative, at Wikipedia.org.

Bibliography

Ashby, W. Ross, *Design for a Brain*. London: Chapman and Hall, 1960.

Hawkins, Jeff and Blakeslee, Sandra, *On Intelligence*. Times Books, 2004.

IBM/Ecole Polytechnique Fédérale de Lausanne (EPFL), http://bluebrainproject.epfl.ch/, 2004.

Lettvin, Jerome Y., "Introduction to Volume 1" in *W S McCulloch.,* Volume 1, ed., Rook McCulloch, Salinas, California: Intersystems Publications, 1989, 7-20.

McCulloch, Warren S. and Walter H. Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity", in *Embodiments of Mind* by Warren S. McCulloch. Cambridge, Massachusetts: The MIT Press, 1965, 19-39.

Maturana, Humberto R., Biology of Cognition, 1970. Reprinted in Maturana, Humberto R. and Francisco Varela, *Autopoiesis and Cognition*: The Realization of the Living. Dordrecht: Reidel, 1980, 2-62.

Maturana, Humberto R. and Francisco J. Varela, *The Tree of Knowledge.* Boston and London: New Science Library, Shambala Publications, Inc, 1988.

Minsky, Marvin, *Computation: Finite and Infinite Machines.* New Jersey: Prentice Hall, Inc., 1967.

Minsky, Marvin, ed., *Semantic Information Processing*. Cambridge, Massachusetts: The MIT Press, 1968.

Pask, Gordon, "A Comment, a Case History and a Plan". In *Cybernetic Serendipity,* ed, J. Reichardt. Rapp and Carroll, 1970. Reprinted in *Cybernetics, Art and Ideas,* ed., J. Reichardt. London: Studio Vista, 1971, 76-99.

Pask, Gordon, *Conversation Theory*. New York: Elsevier Scientific, 1976. [40MB PDF]

von Foerster, Heinz, ed., *Cybernetics of Cybernetics.* Sponsored by a grant from the Point Foundation to the Biological Computer Laboratory, University of Illinois, Urbana, Illinois, 1974.

von Glasersfeld, Ernst, *The Construction of Knowledge, Contributions to Conceptual Semantics.* Seaside, California: Intersystems Publications, 1987.

Wiener, Norbert, *Cybernetics, or control and communication in the animal and the machine.* Cambridge, Massachusetts: The Technology Press; New York: John Wiley & Sons, Inc., 1948.

Winograd, Terry and Fernando Flores, *Understanding Computers And Cognition: A New Foundation for Design.* Norwood, New Jersey:

Ablex Publishing Corporation, 1986.

-end-

[Origin of this content: In 1990 Heinz von Foerster was approached by Macmillan to compose the entry on cybernetics for their 1991 Encyclopedia of Computers and von Foerster kindly referred them to me. The published text was (c) Macmillan Publishing while incorporating a figure created for an earlier purpose. Over time, updates, extensions, and clarifications have been incorporated into the text above. - Paul Pangaro, 3 August 2006]

Related Links

Video — Footage of cyberneticians
Video — How AI arose from cybernetics
Video — Artifacts from Gordon Pask's Conversation Theory

Cybernetics
... as the basis for understanding interaction design
... as an approach to software experience
... as an approach to designing conversations
... for designing organizations
... as an alternative to design thinking

Conversation Theory, an informal introduction

Variety of PDFs of Gordon Pask

Unities acrossVon Foerster, Pask, and Maturana

Ashby's Requisite Variety applied to social systems