

1. Introduction

1.1 Intelligent Systems

General characterization:

An intelligent system has the ability to act appropriately in an uncertain environment, where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral subgoals that support the system's ultimate goal [Antsaklis, 1994].

In order for a man-made intelligent system to act appropriately, it may emulate functions of living creatures and human mental faculties. There are degrees or levels of intelligence that can be measured along the various dimensions of intelligence.

There are a number of alternative definitions of intelligent systems.

1. Man-made systems and intelligent machines:

Machine intelligence is the process of analyzing, organizing and converting data into knowledge, where (machine) knowledge is defined to be the structured information acquired and applied to remove ignorance or uncertainty about a specific task pertaining to the intelligent machine.

This definition leads to "the principle of increasing precision with decreasing intelligence." Applying machine intelligence to a data base generates a flow of knowledge, lending an analytic form to facilitate modeling of the process.

2. Ability to dynamically assign subgoals and control actions in an internal or autonomous fashion:

Many adaptive or learning control systems can be thought of as designing a control law to meet well-defined control objectives. This activity represents the system's attempt to organize or order its "knowledge" of its own dynamical behavior, so as to meet a control objective.

The organization of knowledge can be seen as one important attribute of intelligence. If this organization is done autonomously by the system, then intelligence becomes a property of the system, rather than of the system's designer.

3. A procedural characterization:

Intelligence is a property of a system that emerges when the procedures of focusing attention, combinatorial search, and generalization are applied to the input information in order to produce the output.

Once a string of the above procedures is defined, the other levels of resolution of the structure of intelligence are growing as a result of the recursion.

1.2 Control and Intelligent Systems

The concepts of intelligence and control are closely related and the term "intelligent control" has a unique and distinguishable meaning.

An intelligent system must define and use goals. Control is then required to move the system to these goals and to define such goals. Consequently, any intelligent system will be a control system.

Conversely, intelligence is necessary to provide desirable functioning of systems under changing conditions, and it is necessary to achieve a high degree of autonomous behavior in a control system.

Since control is an essential part of any intelligent system, the term "intelligent control systems" is sometimes used in engineering literature instead of "intelligent systems" or "intelligent machines."

One more alternative characterization of intelligent (control) systems is the following:

An intelligent control system is designed so that it can autonomously achieve a high level goal, while its components, control goals, plant models and control laws are not completely defined, either

because they were not known at the design time or because they changed unexpectedly.

1.3 Dimensions of Intelligent Systems

There are several essential properties present in different degrees in intelligent systems.

Adaptation and Learning. The ability to adapt to changing conditions is necessary in an intelligent system. Although adaptation does not necessarily require the ability to learn, for systems to be able to adapt to a wide variety of unexpected changes, learning is essential.

Autonomy and Intelligence. The autonomy in setting and achieving goals is an important characteristic of intelligent control. When a system has the ability to act appropriately in an uncertain environment for extended periods of time without external intervention, it is considered to be highly autonomous.

Structures and Hierarchies. In order to cope with complexity, an intelligent system must have an appropriate functional architecture or structure for efficient analysis and evaluation of control strategies.

1.4 Working Definition

In view of the above, a working characterization of intelligent systems, or of (highly) intelligent (control) systems or machines, that capture the essential characteristics present in any such system is:

An intelligent system must be highly adaptable to significant unanticipated changes, and so learning is essential. It must exhibit a high degree of autonomy in dealing with changes. It must be able to deal with significant complexity, and this leads to certain sparse types of functional architectures such as hierarchies.