NEURAL NETWORK AND INTELLIGENT CONTROL - PART I

A.K. SWAIN AND B. SUBUDHI

Neural networks are analogous to biological systems, and intelligent control systems are but an attempt to emulate the logical powers of the human mind. Articles in this series are intended to demystify the various intricacies of the two inter-twined topics.

Humans are intelligent because evaluation has equipped them with a richly structured brain. This structure, while serving a variety of functions, enables them to learn. A certain critical degree of structural complexity is required of a network before it can become self-modifying — no matter how sophisticated its reinforcement rules — in a way that we could consider the network to be intelligent.

Intelligent control systems (ICS) deal with intelligent machines. Technically intelligent machines imply sophisticated sensors and actuators, very powerful microprocessors, computers, algorithms and software. Intelligent control systems are those systems which integrate traditional control concepts with real-time fault diagnostics and prognostic capabilities. From non-technical angle, intelligent systems perform like humans with higher yield and better quality.

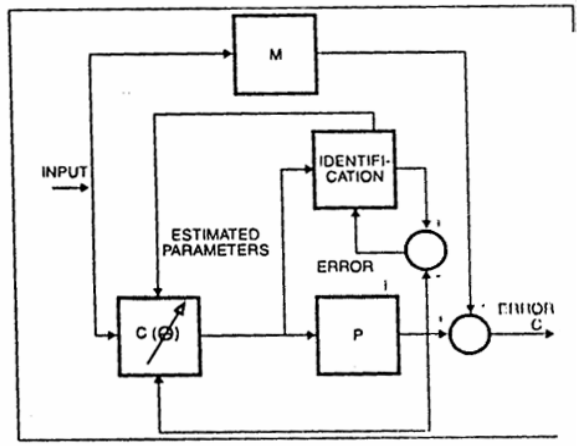

Fig. 3: Schematic representation of indirect adaptive control method.

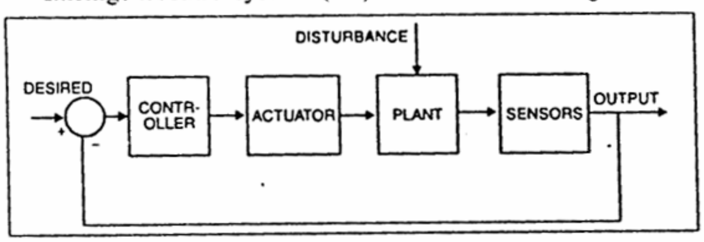

Fig. 1: Simple feedback control system.

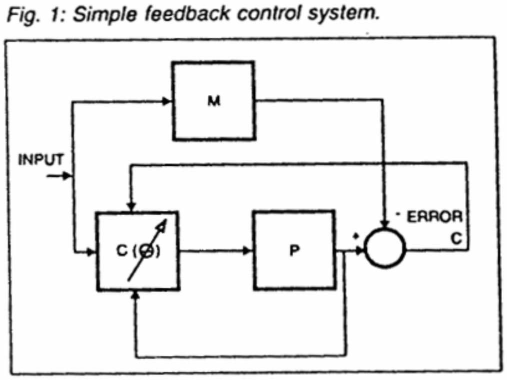

Fig. 2: Block schematic cf direct adaptive control method.

The authors belong to the Department of Electrical Engineering, Indira Gandhi Institute of Technology, Sarang, Orissa.

During the last decade there has been much interest in investigating the development of intelligent control systems. An ICS has unique features like learning and decision-making that enable it to reason about dynamic environments adaptively and predictively and to make decisions at both micro and macro levels of system operation. At present there are three classes of intelligent controllers: expert controllers, fuzzy controllers and neural controllers.

A great deal of research activities is

One cannot exactly define what an intelligent syste[m] is but one can know when someone or something is intelligent.

currently going on in the computat[...] properties of highly interconnecte[...] works of simple processing units, [...] artificial neural networks, which [...] similarities with the structure of [...] logical nervous system.

One cannot exactly define w[...]

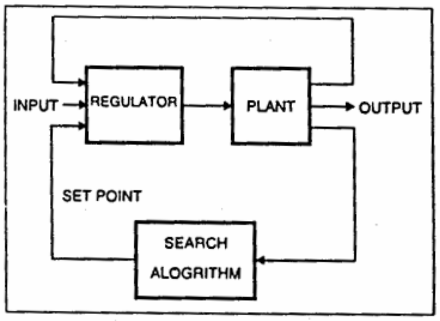

Fig. 4: Block diagram of extremum control system.

intelligent system is but one can know when someone or something is intelligent. If a one-year-old child is able to identify the letters of the alphabet, she is considered intelligent but not a five-year old who does the same work. When a final-year engineering student gets all the jobs for which he undergoes some test, he is intelligent. A good cricketer or a chess player is also considered to be intelligent.

The word 'intelligence' should be used carefully for automatic control in order not to expect too much in comparison to a really intelligent human operator. Intelligent control is the next hierarchical level after adaptive and learning control, to replace the human mind in making decisions, planning control strategies, and learning new functions by training.

Nowadays the concept of intelligent controller, intelligent actuator or intelligent interface has become more commonplace with the advancement of technology.

The present control scenario

The last decade has seen the rapid development and expansion in the control engineering knowledge, methodology and strategy. By control we mean interacting and reasoning about the real physical world for some specified purpose, i.e. to alter or improve the system behaviour. Automatic control, in its simplest form, is a feedback control and is illustrated in Fig.1. A higher level of automation can be achieved by incorporating fault diagnosis, condition monitoring, supervision and training, along with tuning and adaptation.

At present billions of simple feedback systems are in use in industries for controlling or regulating the plant variables. Most of the industrial applications are complex, nonlinear and uncertain in nature. The greater the ability of the control system to efficiently cope with these, the more intelligent it is.

The ability of a system to sense the environment and adapt the nonlinear behaviour (adaptation), process the information in dependence on the load (learning), supervise all relevant elements and diagnose the fault (supervision) for repair and maintenance, generate and execute control (decision for action) constitutes an intelligent control. The basic requirements for all types of controls to be designed are accuracy, robustness, stability, speed, sensitivity and optimality.

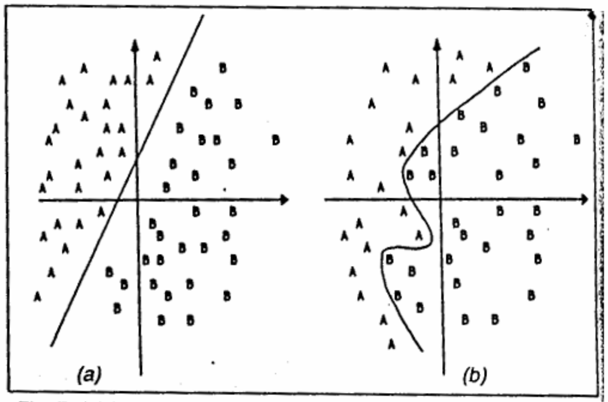

Fig. 7: (a) Linear separation; (b) nonlinear separation.

The word 'intelligence' should be used carefully for automatic control in order not to expect too much in comparison to a really intelligent human operator.

Control perspective

Adaptive control. Adapt means to change or adjust a behaviour to conform to new circumstances. In a symposium in 1961, an adaptive control system was defined as any physical system that has been designed with an adaptive viewpoint. It is a process by which a system monitors its own performance and proceeds to improve it.

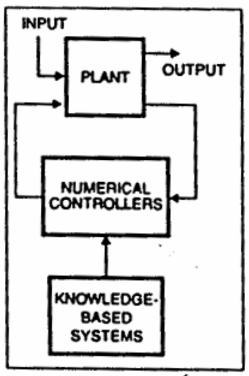

Fig. 5: A knowledge-based expert control system.

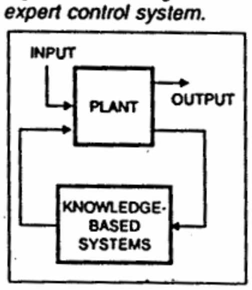

Fig. 6: Block schematics of qualitative control system.

Adaptive systems are inherently nonlinear, so their behaviour is quite complex, which makes them difficult to analyse. Due to its complex nature an adaptive system has connections with nonlinear systems, stability, system identification, recursive parameter estimation, stochastic and optimal control.

There are two methodologies for adaptive control—direct adaptive control and indirect adaptive control. In direct adaptive control the control action depends upon the output error, as shown in Fig.2. In indirect adaptive control (Fig.3) first of all the unknown part of the system is estimated, and then it is used to determine the control input.

Since the mid 1950s there have been a number of applications of adaptive control. The advent of microprocessor drastically increased the number of applications and made the technology more cost-effective. Today there is an increasing number of industrial applications like aerospace, process control, robotics, power systems, ship steering, medicines, etc.

Extremum control. Extremum control means to track a varying minimum or maximum. Fig.4 shows a block schematic of a simple extremum control.

These systems are essentially nonlinear. The aim of the controller is to determine the optimum operating point and to track it if varying. It is also related to optimisation techniques. It has its applications in gas furnaces, chemical reactors, combustion engines, wind mills and hydel stations. A combination of extremum control with adaptive control will be of great practical interest.

Expert control. Expert systems essentially extract the human knowledge at high level to solve the problems. The applicability of an expert system along with conventional numerical algorithm-based control can be enhanced after encoding it into expert rules for the adjustment of the control, either by modifying the control algorithm or by replacing it altogether with another approach. This method is called expert control, and the block diagram of such a system is shown in Fig.5. This is very attractive, as it uses the existing techniques and skills.

Qualitative control. Qualitative control uses artificial intelligence techniques directly to model the system. As shown in Fig.6, it directly closes the feedback loop, i.e. qualitative representation of the control policy to compute the value of the control variable. So practical controllers must output a numerical value; in other words, the qualitative value must be approximated by a numerical value, i.e. a symbol to signal transformation. One common example of this approach is fuzzy logic controller (FLC). Metalevel control can be used with qualitative controllers as, for example, self-organising fuzzy-logic controllers (SOFLC).

Learning systems which have strong relationship to adaptive control try to describe or mimic the human learning ability.

Learning systems. Learning, in a broader sense, is the capability of a system to permanently modify its structure, to adapt its behaviour to the environment. Learning systems which have strong relationship to adaptive control try to describe or mimic the human learning ability. These systems are in use with names neural networks, connectionist models, etc.

Pattern recognition. The first adaptive and associative machines developed around 1960 were interpreting statistically the patterned variables such as speech, hand-written symbols, etc. This was simply a categorisation and classification task, which is illustrated in Fig.7.

This research area was later known as pattern recognition or artificial perception. The term 'pattern' in pattern recognition research implies an organised system of information. A pattern can be almost anything imaginable. The ability to recognise and respond to information patterns is a fundamental aspect of all intelligent systems.

(To be concluded next month)