THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES FOR INTELLIGENT CONTROL OF DYNAMICAL PHYSICAL SYSTEMS

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EXTENDED ABSTRACT

In recent times, there is a growing concern over the safe operations of control systems in industries after the accidents at Bhopal, Chernobyl, Windscale, Seveso, Flixborough and Three Mile Island. Most of these accidents has been caused or exacerbated through human error in controlling the process systems. This has led to increasing concern among the scientific community and industrialists over the safe and reliable operations of control systems in industries. Several techniques have been built to support the process control operations. The control systems should be able to withstand the sudden changes in environments, unmeasurable disturbances, changing reference models and performance criteria, component failures, etc., in order to prevent industrial disaster.

The vast majority of processes in nature and in our man-made world exhibit dynamic behaviour, i.e., they change over time. Some examples are, Process Control in an Industry, weather, Gas pipeline systems, etc. At any point in a time, the state of a system is described by the value of its state variables. The space formed by the values of the state variables is called the "*state space* ". The behaviour of a dynamical systems can be described as a vector field on the state space. This field represents the state transitions. For every state in the state space one can determine the evolution by following its associated vector. Hence, the vector field describes trajectories on the state space. All control problems involve manipulating a dynamical system's input so that its behaviour meets a collection of specifications constituting the control objectives.

The science of process control can be divided into two large families namely,

(a) sequential control and

(b) continuous control.

Continuous control (or regulatory control) concerns maintaining physical values at desired levels (set point) by continuous correction to the control signal sent to the process. Continuous control is an effective means of compensating for small perturbations which do not modify the process status. Sequential control, on the other hand, develops ordered sequences of commands to switch the process between different statuses.

Currently, control theory can deal with a variety of control problems. For example, tremendous success in areas where the system is well defined, such as in missile and space vehicle guidance, has been achieved. However, it has failed to cope with the practicalities of many industrial processes, despite the development of a huge body of mathematical knowledge.

The advancement in the field of computer science has cause substantial changes in process automation. Advances in control systems has led to the development of so-called "higher autonomous functions" such as

- Operation guidance
- Process optimization
- Production management
- Emergency/security control
- Emergency management

The application of these autonomous tasks to complex systems faces us usually with a lot of features making substantial trouble. Some are :

- markedly incomplete information on the system and running processes
- fuzzy and/or confusing information.
- important characteristics of the system cannot be fully formalized by classical methods.
- disturbances are characterized by high amplitudes.
- large volumes of data.
- the set of admissible control actions cannot be overlooked.

Hence, as a result of this complexity, the classical methods of mathematical modeling and control fail. The rapid changes and increasing complexity of social and technological systems had led to the demand of more powerful control theories and systems. Although several adaptive control techniques have been introduced, it is not strong to many real-world problem domains where the degree of uncertainity is too high and the computational complexity grows geometrically with the number of unknown parameters and its inherent linear nature of an assumed dynamic model. With an environment which is only partially known, it is desirable that the system be able to gradually learn the characteristics of the environment so as to improve its control strategy. Hence, there is a need for systems which possess some form of "Intelligence" to be robust in nature. Changes in environments, unmeasurable disturbances, changing reference models and performance criteria and component failures are some of the characteristics which necessiate intelligent control. The system should be able to learn from its experience in order to achieve some form of "intelligence".

Today the development in Artificial Intelligence (AI) has reached a stage which will help to reduce these complexities. Classical control methods identify locally optimal control actions based on mathematical models of monitored processes. By contrast, artificial intelligence methods identify control actions that are locally and globally desirable, based on knowledge and reasoning about monitored processes. Computer technology has reached a point that 'machine intelligence' can be incorporated in many of the systems that we use daily. During the past decade there has been a major interest in investigating the development of Intelligent Control Systems. Today the term intelligent control has been used in a variety of forms and meanings. Intelligent Control Systems have two unique features that differentiate them from conventional control systems. They are "ability to make decision" and "learning capability"

AI systems should approach the control problem as a real-time planning problem. It operationalizes intelligent control problem solving as achievement of (at least) the following behavioural goals :
(1) Make explicit control decisions that solve the control problem.
(2) Decide what actions to perform by reconciling independent decisions about what actions are desirable and what actions are feasible.
(3) Adopt various grain-size control heuristics.
(4) Adopt control heuristics that focus on whatever action attributes are useful in the current problem-solving situations.
(5) Adopt, retain and discard individual control heuristics in response to dynamic problem-solving situation.
(6) Decide how to integrate multiple control heuristics of varying importance.
(7) Dynamically plan strategic sequence of actions
(8) Reason about the relative priorities of domain and control actions.

Based on both the many professional publications as well as observations of industrial practice, it can be seen that three Artificial Intelligence based approaches seem to have had significant impacts in the area of control in recent times. They are :

• Knowledge-Based Systems

• Machine Learning and

• Fuzzy Control

These three approaches, all of which can be classified as falling into what has now become known as "Intelligent Control", seem to offer much potential.

The application Expert/Knowledge-Based System techniques to process control has given rise to the term "expert control" Expert/Knowledge-Based Systems can assist in process observation and emergency control. Two techniques can make this help possible. An expert system can indicate process states implied by sampled data from process sensors. These process states can be used as decision criteria that leads to appropriate recommendations and emergency actions. While traditional expert system shells have often been applied in diagnostic or consultative applications, they have not been used as much in real-time applications such as process control, where reasoning has been driven by high-input data rates and the need to provide an accurate response within a critical response time interval. The use of real-time expert systems in manufacturing and process control applications is propelled by several trends in manufacturing automation technology. A new class of tools is providing an enabling expert system-based technology while offering performance that can handle real-time and mission-critical applications. The author believes that expert system technology offers a completely new way of augmenting the expertise of operators, and can also offer cost benefits in the area of process optimization, scheduling and control.

Machine Learning Research spans almost four decades. Much of the research has been to define various paradigms, establish the relationships among them, and elaborate the algorithms that characterize them. Much less effort, relatively speaking, has been devoted to bringing machine learning to bear on real applications. Recently researchers have focussed more on applying machine learning to real world problems. Recent resurgence in research of neural networks has offered the advantage of parallel/distributed processing of immense amount of information and performance improvement through learning. These new abilities have motivated new studies in applying neural networks in learning, identification and control of dynamical systems and has been found to be extremely successful. The inherently parallel nature of the signal processing performed by these models, and the commensurate increase in the speed with which this processing can be performed, would alone merit attention from control engineers. Moreover, the additional properties exhibited by the distributed mappings implemented by these "neural networks", such as noise rejection, fault tolerance, and graceful degradation, as well as the adaptive manner in which the mappings are originally formed, suggest that these techniques could be profitably employed as the starting point for a variety of new control algorithms. Several other machine learning techniques namely, induction, reinforcement learning, Q-learning, etc. have been successfully applied to control problems.

The application of fuzzy set theory in control is gaining more and more attention in industry. Control systems are essentially relationships or mappings between inputs and outputs of a controller. A fuzzy algorithm can be used to represent such a mapping as a set of situation-action pairs, between a fuzzy input variable and the corresponding fuzzy output variable defined over disparate universes of discourse. The use of fuzzy control in a cement kiln, for example, was probably one of the first large-scale applications of fuzzy control, but over the past few years many new applications have been reported. Indeed, even special purpose hardware is becoming commercially available.

In the paper, we describe the applications of artificial intelligence techniques for intelligent control of dynamical physical systems.