Lecture Series on

Intelligent Control

Lecture 3

Learning Modeling & Control

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Learning Modeling and Control

Need for Learning:

The *inflexibility* of many industrial robots has been one of the principal reasons for the reduction in the growth rate of robotic industrial applications [Albus, 1990].

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Learning Modeling and Control

By introducing *learning elements* into the control systems, the plants will become more flexible and better able to deal with complex, real-world environments.

Learning is an integral part of any IC system and exists at many levels of abstraction.

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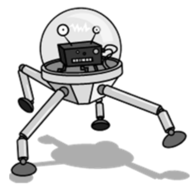
Learning Modeling and Control

In the dynamic control techniques, learning algorithms have been studied in the *adaptive control* field for many years [Åström and Wittenmark, 1989, Narendra and Thathacher, 1989],

and these have been complemented by research into adaptive neural and fuzzy networks [Wang, 1994].



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Need for Learning:

Higher in the IC architecture, learning can be as simple as internally updating its **world model**, or

complex learning/exploring systems may be used [Sutton, 1990].

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Each task requires an appropriate learning system, as the problem structures are generally different.

Therefore, learning systems should be aimed at particular problems and should always use the maximum amount of relevant *a priori* information.

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Need for Learning:

Within the specific context of dynamic processes, learning may be required for the following reasons:

- prior knowledge about the plant's structure is unavailable or only partially known;
- time-varying plant;
- partially known or time-varying operational environment;
- improve the performance of the plant over a wide range of operating conditions;
- increased flexibility; and
- reduced design costs.

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Need for Learning:

It should be noted that other techniques such as *gain scheduling* can provide similar benefits if the problem is structured appropriately.

Learning control techniques generally use a basic model that is inherently *nonlinear*. This is an important point, because it enables *global* plant models to be constructed rather than the locally linear models used in adaptive control.

Therefore, there is *no need* for the continuous adaptation which is necessary to compensate for changing operating points once a satisfactory model has been learned.

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Learning and Adaptation:

To *adapt* is "to change a behaviour to conform to new circumstances" [Åström and Wittenmark, 1989], whereas *learning* generally implies a gaining or transfer of knowledge.

Adaptive control techniques have been well developed over the past thirty years and many convergence (and stability) rules and theories have been developed for *linear* plants, and under certain circumstances these can also be applied to various *nonlinear* processes as well.

Learning algorithms are generally aimed at ill-defined processes and use heuristics, for instance to construct rule-base systems.

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Learning Algorithms:

Many different algorithms can be used within learning control schemes and their knowledge structures generally reflect the type of application.

The three most popular types of learning algorithms are currently *artificial neural networks* [Miller *et al*, 1990], *fuzzy logic* [Wang, 1994], and *expert systems* [Hunt, 1992].

These categories are not distinct as there exist strong relationships between fuzzy and expert systems which incorporate uncertainty,

as well as between fuzzy and some associative memory neural systems

and some expert systems can be implemented within a neural network architecture.

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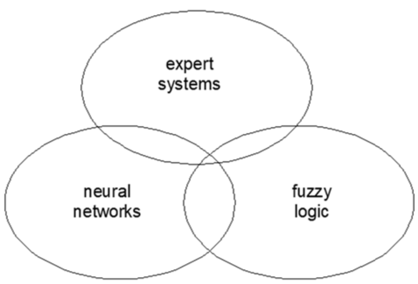

Three learning algorithms with inter-relationships

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Learning Algorithms:

Central to the problem of learning is the ability of the algorithm to *generalize* correctly from a limited number of training samples,

which means that the algorithm must *interporate* and locally *extrapolate* with sufficient accuracy.

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Most learning algorithms can be classified according to their *modeling*, *learning*, and *validation* properties.

The *modeling* capabilities of an algorithm determine the range of nonlinear functions which it can reproduce exactly and any implicit smoothness assumptions made by the network.

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Learning Algorithms:

The *learning rule* used does not generally affect the underlying modeling capabilities of the algorithm, although the chosen model structure influences its rate of convergence and can even determine the type of learning rule that should be used.

Finally, any practical application of a learning algorithm requires *convergence, stability and correctness* tests which can verify what is being learned. If an algorithm learns, it also forgets and it must be verified that the behavior being stored is desirable.

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