# From Control to Information Processing

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## 1. Introduction

In this highly developed IT era, we are facing the unprecedented challenges arisen from rapidly developed economy and social progresses. Today, people can easily get information from network. With the high quality computers large amount of information could be processed in high speed. In the past, people always did what they could, but today, they expect to do better rather than what they can. Many challenging tasks require us to make full use of effective information to find the high-performance, low-cost and economical solutions. These tasks not only come from the traditional industrial and aero-/astronomical fields, but also from all fields of society and economy, such as the security and optimal management of high-speed information network, the rules mining in gene engineering, the optimal scheduling and planning of large engineering projects etc. The description of the problems is no longer limited to the pattern in the traditional control theory, even more, some problems have come into our fields of vision, but we still haven't found the appropriate ways to describe them.

These challenges also reflect the mutual dependence and idea immersion of different disciplines. For example, in the past the traditional manufacturing only emphasized the design and processing and the researches were focused on the design of high performance mechanism and rational processing procedure. But today in the advanced manufacturing systems, the concepts of system and optimization have been introduced into the field of manufacturing, and IT becomes the most important part of advanced manufacturing. This kind of immersion is bi-directional. On one hand, in traditional disciplines, more and more information and automation technologies have been introduced, which form the branches of automation in these disciplines, such as electrical power system automation, manufacturing automation, nuclear engineering automation etc. On the other hand, people in automatic control field also incessantly infiltrate in various fields, incarnate the power of control and automation by solving challenging problems

in these fields, and thus promote the development of automatic control discipline. During this interdependent development process, the field of automatic control is facing great challenges. After people of other fields get acquainted with automation technology, can people in the field of automatic control fully embody their values? This is an urgent problem that we should answer.

## 2. The Extension of Control to Information Processing

The concept of control existed from of old, but the control theory was not formed only until the mathematical models were found. The frequency domain control theory formed in the 50s is based on the transfer function, while the modern control theory was developed in the 60s only after the successful description of dynamical systems by the state space method. These traditional control theories have solved a large amount of problems in industry and engineering, and are still widely used now. But with the severe requirements to solve various kinds of complex control problems, the limitation of these theories has appeared little by little. The model, which is the basis of traditional control theory, is established from the knowledge and regular description of the dynamic behavior of plants. The control quality largely depends on the accuracy of the models. With the more and more complexity of the plants and the tasks, the system modeling also faces the new difficulties.

First of all, for rather a part of plants, like the complicated industry processes, we can not build the accurate mathematical models for them. The present modeling technologies can only describe the main dynamic characteristics at most, which inevitably results the modeling errors and unknown disturbance. From the perspective of causality, it is impossible in nature to give the accurate description for unknown plants. Therefore, the precondition of accurate models does not exist in most of cases. It is also because of this that the technology of system identification is increasingly developed. The approaches of dealing with the model uncertainty, like robust control, predictive control etc. are also developed rapidly. Especially, different kinds of intelligent control technologies emerge as the times require which desalts the concept of models.

Secondly, for some increasingly complicated control problems, it is almost impossible to describe them with the present control theories. For instance, the descriptions of the manufacturing scheduling as the discrete events dynamic systems, the optimization of communication network, etc., are quite different from that of transfer functions and state space methods. And in the CIMS of large industrial production, the so-called models are only system architectures, functional models and information models. Here, the concept of traditional models has been replaced by the regularly expressed information. For these problems, the traditional control theories based on the mathematical models are incompetent.

Aiming at the above problems, in the past two decades, people in the control circle have made active efforts to adapt to the new tasks and challenges. On one hand, based on the traditional control theories, adaptive control,

robust control, predictive control and intelligent control have been fully developed, which desalt the requirement on the models and take the uncertainty into account. Among these, some approaches still follow the ideas of traditional control theories, but reduce the needs for models. The emphasis is put on finding control strategies with the inaccurate models under uncertain environment. Other technologies, however, such as expert system, neural network, fuzzy set etc have turned to construct the new regular description directly from the information in order to easily acquire the dynamic regularity among the original information. On the other hand, people have broken through the traditional control conception and surveyed the tasks to be solved from a higher level of vision. New concepts of models according to the characteristics of tasks have been proposed, such as in discrete events dynamic systems. Furthermore, based on that new control conception and methods were developed which are quite different from the traditional ones. We can say that, it is because of the above development that the present control fields can present various rich researches. The control theory based on the frequency domain and the state space methods forms its own system with self-contain and complete features. But today, due to the multi-aspect development in control theory, it is difficult to generalize it with a uniform framework or a new theory system. This kind of generalization can only be proceeded in a higher level, that is, the control theory is stepping from the model to information.

### 3. The Advantages of Control Circle

The control concept from the traditional model-based to the information-based is not only a kind of development, but also a kind of regression. In fact, control, in its original sense, means how to use the appropriate method to satisfy the certain requirements of tasks when we take command of the regularity of the plants. The control theory based on the traditional models is just to describe this process through modeling, control and optimization. But we cannot understand that this is only the mathematical model based control and optimization. Once the control concept has been generalized from traditional model-based to information-based, then various information-processing technologies will provide us unprecedented wide development space.

Today, with high developed IT, information and information processing have been mastered by all fields of life. In many fields like mechanical manufacturing, environment engineering, communication etc., people have already learnt to use various kinds of information technologies to deal with the problems that they want to solve. Therefore, how can people in the field of control embody their values?

The characteristics of control discipline lies in that it is aimed at the general regularity of modeling, control and optimization. It provides general insight and technical means of how to do things better under different environments. The expression in the traditional control theory is based on the mathematical models, which does not involve any concrete physical plants. But because it describes the general laws, control

form the corresponding theoretical system, and further instruct the applications in various fields, so as to fully embody the control's characteristics and values. Generally speaking, people in the control circle should fully take their advantages in the following aspects:

- The implementation of control is a systematic behavior. Any control system can be described as an information processing system in the information level. The experts in the special fields often study the plant characteristics by using the information technology (including the technological mechanisms and the performance analysis) and make some optimization according to these characteristics (such as the optimal design), while the control experts engage their research more from the perspective of system. Control science, as the incarnation of a kind of general regularity, is definitely bound up with the system conception. The control experts are better at observing and studying the plants from the perspective of integral system than the field experts. With the increasingly huge and complex plants, this kind of advantage will appear more obviously. In the modern manufacturing integrated systems and the process integral automation, the control experts always play a key role, which clearly shows that.
- The core of control is feedback and optimization. It contains the most full and rational use of known and unknown information. The concept of feedback is just the soul of modern cybernetic. Although the traditional feedback control theory is based on the mathematical models, the model form should not limit the concept and application of feedback. Compared with the control experts, the field experts pay more attention to implement the optimization from the models of plants. When concerning the cases of no models or uncertainty, they are often powerless. For example, to optimize the communication networks, we can greatly improve the network performance by introducing feedback somewhat. This is very natural and easy for the control experts. However, people in the communication field often cannot think of this first. So, one of the advantages of control experts is use the basic ideas of cybernetics to consider the effect of uncertainty while optimizing system, and improve and better the system's performance through feedback.
- The concept of control is closely bound up with the information processing. Control science not only becomes more and more mature in the mathematical model based theory, but also makes good progress in the form, framework and technical means of dealing with the information processing, such as the hierarchical structures, distributed control, fuzzy control, neural network control and optimization etc. This not only establishes the groundwork from control to more general information processing, but also makes the control experts combine the new developments with the traditional control theory, thus presents the unique adaptation, flexibility and rationality in the means of information

processing, which embodies the control values.

In fact, we don't necessarily worry about the pressure from the development of information technology and its wide applications by the experts of various fields to solve the confronted problems. People in the field of control always stand higher than the field experts as their deep understanding and flexible applications of system theory, cybernetics and information theory. They have more ways and thoughts to solve problems with the increasingly complicated plants and tasks. Here, of course, a precondition is, control should not be understood only as traditional theory based on models, but in general sense a kind of recognizing the plants and implementing a generalized control to meet certain requirements through effective information processing based on system theory, cybernetics and information theory. It is to say that control must be developed from the model-based to the more general information-based.

## 4. Strength Control Education to Adapt to the IT Era

The above discussed can also be considered as in which aspects should the future control experts embody their features and abilities. In order to adapt to the needs of IT era and the development of control to the general information processing, we must reform our control education in the university, especially the graduate education. To cultivate the talents who can adapt to the needs of economical and social development, apart from the solid basis, we deem that the following aspects should be strengthened.

- the general conception of cybernetics, system theory and information theory, and the control methodology;
- the basic knowledge of modern computer science and communication science;
- the new development of control theory based on the models in the aspects of handling with the uncertain information;
- the novel approaches and technologies of information processing;
- the optimization theory and technology;

We are making great efforts to explore, and sincerely hope that the colleagues home and abroad to supply your previous comments.