Identification of Backlash Nonlinear System by use of M-sequence and correlation

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Abstract

This paper describes a new method of identification of backlash nonlinear systems by use of M-sequence correlation method. In this method, we can obtain not only Volterra kernels of up to 3rd order of the nonlinear system, but also the width of the backlash element from observing the crosscorrelation between the input and the output. Here strictly speaking, a multi-valued nonlinear system such as backlash element can not be expressed by Volterra kernel representation mathematically. But in practice, we encounter many cases where it is difficult to treat them mathematically but they can be controlled from experience. So we here dare to suppose that backlash nonlinear system can be approximated by Volterra kernel representation. Simulations are carried out on a nonlinear system consisting of linear part plus backlash element. And Volterra kernels are measured. The output calculated from the observed Volterra kernels is in good agreement with the actual output. And we show that we can obtain the width of backlash element, which is one of the most important parameters, by observing the maximum value of crosscorrelation function between the input M-sequence and the output.

1. Introduction

Nonlinear systems having backlash element appear frequently in industrial systems such as mechanical servo control systems etc. For example, backlash type nonlinear element exists in a mechanical transmission systems. An interval of transmission is a kind of nonlinear backlash characteristic. When the main tooth wheeler makes a change of direction, the following wheeler won't change until the interval is used up. In the iron magnetic material, the magnetic material hysteresis is also a kind of nonlinear backlash characterictic.

The treatment of backlash nonlinear systems is sometimes difficult, because it has multi-valued nonlinearity. In a sense, this kind of multi-valued nonlinear element is one of the most difficult nonlinear systems for identification in practical industrial control systems.

There are many researchers who have tried to indentify this kind of system by various methods.

Simpson and Power[3] have shown that a method of identification developed for a class of system containing a zero-memory nonlinearity is applicable to certain types of nonlinear elements with memory. So here we try to apply Volterra kernel method, which is originally for zero-memory type nonlinear system, to backlash system which is memory type nonlinear system.

Maurice Fréchet showed that any continuous functional can be represented by a series of functionals of integer order whose convergence is uniform in all compact sets of continuous functions. Therefore, Volterra kernel expansion method can only be used for those nonlinear systems which are continuous for input-output relation, and single valued, theoretically. The nonlinear systems having backlash type element are multi-valued as far as input-output relationship is concerned, so these nonlinear systems are, strictly speaking, not suited to Volterra kernel representation.

However, Volterra kernel expression of nonlinear system is one of the most useful method for representing nonlinear systems, we would like to know what would be the result if we apply Volterra kernel identification method to nonlinear system having backlash element.

In this paper, we apply the method of the application of Volterra series with M-sequences to the identification of a nonlinear system consisting of backlash characteristics. The system shown in **Fig.1**, second-order system plus backlash nonlinearity is investigated.

In this method, M-sequences are applied to the nonlinear system and the crosscorrelation function between the inputs and the outputs are measured. From the crosscorrelation function ,we can get not