A Survey on Method of System Identification

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Abstract. In this paper the advance in the study of system identification is summarized. Some traditional system identification methods are introduced, Least Squares Method, Recursive Gradient Correction and Recursive Maximum Likelihood. Some disadvantages are introduced too so that some new identification methods based on neural network, genetic algorithms, fuzzy logic and wavelet network are presented. After all, one system identification method based on adaptive filter, the method has been usually used in active vibration control.

Introduction

In the Vibration control, identification, state estimation and control theory are three mutual penetrable domain, along with the increasingly complex control process, the improvement of the control theory, the mathematical model of controlled object higher accuracy are put forward. System identification is a kind of modeling method, the different subject areas correspond to different mathematical model, In other words, the development of different disciplines depends on whether the process of its mathematical model is established or not. In the early 1960s, the definition of the system identification has been given by Zadeh\textsuperscript{[1]}: "identification is on the basis of the input data and output data, determine a equivalent model with the measured system from a given set of model class". Mathematical modeling is a mathematical expression on the system of the internal relations between physical quantities, involved in control system design and analysis of the mathematical model of general mathematical model for dynamic. While from a practical point of view, get completely equivalent model is very difficult, so the system identification is actually a suitable approximate to actual system.

The purpose of system identification is based on information measuring system, under the rule of some significance to estimate unknown parameters of the model, in order to obtain estimates \(\hat{p}\) of the object parameter \(p\), usually adopt the method of approaching step by step. According to the previous moment output to budget out the current moment the system output prediction value, and the prediction error compare to the actual output \(e(k)\), then the output prediction error will be feedback to the identification algorithm, under the condition of certain standards, to calculate the moment of the model parameters are estimated\textsuperscript{[2]}, in order to update the model parameters, so the iterative cycle, until the corresponding criterion function minimum, identification of the model reference estimate at this time as the parameters. Identification algorithm is very important for the calculation of parameter estimation. To the same system, different identification algorithm may get different identification parameters. At First, the paper introduce the classical identification algorithm, points out its defects in the
present application, and then make the simple review of the the modern method of system identification in recent years, finally the application of adaptive filter in the system identification is introduced.

**Traditional Methods of System Identification**

The classic system identification methods have been developed comparatively perfect, including step response, impulse response, frequency response method[3], least square method[4], gradient correction method[5], maximum likelihood method[6], etc. Least squares (LS) is a classic, because of the most basic identification algorithm, the principle of simple, rapid convergence and easy to understand and programming implementation, it is the most widely used method. While the least square method is not consistent, there is deviation, in order to overcome the lack of it, form the improved algorithm based on least squares: recursive least squares (RLS), forgetting factor recursive least squares (FFRLS) and recursive least squares (RELS) wider, generalized least squares (GLS), auxiliary variable method (IV), and the general method and other methods of combining the analysis method of least squares step(COR - LS) and the stochastic approximation algorithm. Gradient correction parameter estimation method: along the negative gradient direction of criterion function, gradually correction model parameter estimates, until the criterion function to achieve the minimum. The parameter estimation algorithm is simple, real-time computation is small, but the slow convergence speed. Maximum likelihood (ML) usually take noise frequency density function as the likelihood function, special noise model has good performance, has the good progressive nature, but the large amount of calculation, may be a local minimum value of the loss function.

With constantly improvement of human industry, more and more systems are mostly uncertainty of complex systems, for this type of system, traditional identification algorithm is difficult to work, the traditional recognition algorithm has some disadvantages, such as[7]:

a. The identification algorithm based on the least squares generally require a certain input signal and need to have change, the conditions in many of the closed loop control system can be satisfied, in some dynamic prediction system and process control system ,input signal often cannot be obtained or cannot be changed, so the traditional algorithms cannot be directly applied.

b. Traditional identification generally have good precision for linear systems, but for nonlinear system identification ability will be a great discount, can't get satisfied recognition effect.

c. It is often helpless for some complex system structure.

Above all these problems in identification, would leading to great difficulties in practical application, in the face of increasingly complex systems, a satisfactory precision, we need to seek the new identification algorithm to solve the problem.

**Modern Methods of System Identification**

The development in Research of control theory and artificial intelligence laid a solid foundation for the development of the new identification algorithm, aiming at the existing deficiency of traditional identification algorithm and the limitations of linear system, the neural network, genetic algorithm, wavelet neural network, fuzzy logic is applied to system identification, greatly increase the nonlinear approximation capability. Here is a brief introduce several kinds of algorithms.
**Neural Network System Identification Algorithm**[8]. Artificial neurons are under the development of the research that experts according to the characteristics of biological neurons in research of engineering application, the different types of neural network has its own excitation function and the learning method. Neural network has good nonlinear tracking ability, self-learning ability to adapt and parallel information processing ability, offers a new way for nonlinear system identification problem. In identification of nonlinear system, it can according to neural network of nonlinear static or dynamic system to identify the structure, using nonlinear approximation capability of neural network, to simulate the actual system input and output relationship, using adaptive characteristics and learning ability, it is easy to get algorithm, which is easy to implement in engineering and get into the learning of neural network model. The most representative network model is the one with back propagation of BP (back propagation), not rely on model function, even not know the mathematical relationship between input and output in the identification system, so long as input samples, the network structure and output teacher signal have been given, and give a set of input samples, corresponding network output, can be got by using the output signals and the teacher's difference to fix network weights and threshold, until meet the requirements. While its convergence speed too slow, the network is too sensitive to initial values, so that the local minima problem may be exist. Faced with the problem, by changing learning factors and using the second derivative of target function information to improve the accuracy of network training method and the training speed of precision of the neural network. Also by adopting augmented kalman filter learning method, and there is no need to guess the learning efficiency, the algorithm have the convergence speed, high accuracy. Its basic thought is to put the network weights as a state of the corresponding dynamic system, using augmented kalman filter estimation to get good results.

Compare with the traditional identification algorithm, artificial neural network used for system identification has the following advantages:

a. Neural network itself can be as an identification model so that it does not require the identification of actual system format, this step can save system modeling.

b. Good capability of nonlinear approximation of the nature make sure that the nonlinear system can be identified.

c. The convergence speed of identify does not depend on the dimension of the system to be identified, only related to what the training algorithm of neural network itself is made of.

d. By adjusting the weights of connections between neurons can make the network output to the system output, don't need to change the structure of neurons.

e. As the actual system and neural network identification model, can be treated as physical implementation of systems and can be used for on-line control.

Neural network identification algorithm in nonlinear system identification is very important research value, although there are some problems need to be researched, such as the convergence of learning algorithm, the convergence precision and speed, the real-time identification effect is not ideal, it also has wide application background in complex nonlinear system.

**Genetic Algorithm to System Identification Method**[9]. According to Darwin's theory of evolution, with the aid of computer programming, will have to solve the problem of the string, in a environment where problem would be solved, after generations of change, to pay, finally converge to a bunch of the most to adapt to the environment, namely the optimal solution of the problem. It does not depend on the problem of the model itself, is not easy to limited to local
optimum and the characteristics of implicit parallelism, can search complex and highly nonlinear and multidimensional space in effective way, better solve the least squares method is difficult to deal with delay online identification and the disadvantage of local optimization.

**Fuzzy logic System Identification Algorithm.** Fuzzy logic theory using fuzzy set theory, According to input and output measurement values to identify fuzzy model of the system or not, and has a very extensive application in the field of nonlinear system identification. Identification of the fuzzy logic has the unique superiority, it can effectively identify complex and pathological structure; For large time delay, time varying and multiple input single output nonlinear system, it has better identification precision; Can be obtained by the combination of qualitative and quantitative model of the controlled system. Mainly divided into two levels: identification of model structure and model parameters identification. Typical identification methods including fuzzy grid method, the adaptive fuzzy grid method, the fuzzy clustering method and fuzzy search method. The fuzzy clustering method is the most commonly used, as long as set a reasonable clustering index, according to the clustering center determined by the cluster index, the optimal fuzzy input space division could be made.

**The wavelet Network System Identification Algorithm.** Wavelet neural network was presented on the basis of the wavelet decomposition[10]. It is a feed forward neural network. Wavelet analysis has the unique mathematical background, make it have many differences in analysis and design. With compactly supported wavelet and scale function structure of orthogonal, wavelet network has a systematic design method, According to the requirement of recognition sample distribution and the approximation errors to design grid structure and parameters, moreover, clear approximation error estimation are given too, the grid parameters for there is no local minimum value problem. Have a relatively effective and simple modeling method (translation and stretched to reduce wave generating function), can constitute a framework, the framework, or even orthogonal basis, structure of high efficiency and fast convergence speed, and can solve the general problem of "dimension disaster", is a single variable function of progressive optimal approximation, has been widely used in nonlinear system identification.

**Summary**

Over the past twenty years, a rapid development in the system identification, system identification become an important branch of the theory of automatic control. With the development of fuzzy control, neural network, and wavelet analysis, It is inevitable trend that the study from linear phenomenon to nonlinear system, the continuous improvement of the algorithm and the mature, gradually formed a variety of system identification method. For example, combined with the adaptive filtering system identification ,mainly reflected on the error of channel identification, filter acted as the system model to be identified, according to the input signal of system, the error signal, combined with LMS algorithm for the calculation of error signal, complete the update of filter weight vector and error signal reaches a certain criterion. And then, the weight vectors of the filter at this time will be the parameters of the system to be identified, achieve the same control effect. The development trend of system identification in the future will be the improvement of the traditional theory of recognition algorithm, and the emergence of new control theories and algorithms, the formation of system identification method associated with them, make system identification become a comprehensive discipline.
References


