Recursive parameter estimation algorithms.

Abstract: In adaptive control the ARX regression model is mostly utilized for description of given plant dynamics and unknown parameters are estimated by recursive least square method. Unknown disturbances and non-modeled dynamics can cause that the recursive least squares method leads to inadequate estimations. The controller based on these estimated parameters can give poor performance. This paper deals with several well-known recursive identification methods for parameter estimation of ARX, ARMAX, OE (output-error) model in order to improve the self-tuning controller performance and reliability.

Keywords: Recursive estimation, ARX models, ARMAX models, Recursive identification algorithms, forgetting factors.

1. INTRODUCTION

Development in computer technology makes possible to apply adaptive controller in such situation in which classical controller with fixed parameters cannot provide good performance. In adaptive control the identification task is as important as controller synthesis.

The self-tuning controller (STC) is the part of the group of adaptive controllers. STC is based on recursive estimation of parameters of the controlled plant. These parameters are then used in controller synthesis. It is necessary to use sufficiently accurate and reliable recursive identification methods which are able ensure convergence of parameters in relatively short time. The identification for adaptive control have some specificity which leads to the fact that the ARX regression model is mostly utilized for description of given plant dynamics and its unknown parameters are estimated by recursive least square method (Bobal et. al., 2005). Unknown disturbances and non-modeled dynamics can cause that the recursive least squares method leads to inadequate estimations. The controller based on these estimated parameters can give poor performance.

The problem can be avoided by using more complex models (e.g. ARMAX, OE) which better describe the reality than more simple ARX model or eventually other recursive parameter estimation methods have to be used (e.g. recursive instrumental variable). Several recursive parameter estimation methods are described in literature (Ljung, 1987; Soderstrom & Stoica 1989)

In this article we deal with the following well-known recursive identification methods: Least Square Method (RLS), Instrumental Variable Method (RIV), Extended Instrumental Variable Method (ERIV) which are used for estimation of unknown parameters of ARX model, Extended Least Square (RELS) for parameter estimation of ARMAX model and

Prediction Error Method (RPEM) for parameter estimation of ARMAX and OE model in order to improve self-tuning controller performance and reliability.

2. MODEL STRUCTURE

The basic step in identification procedure is the choice of suitable type of the model. The structure of the model should sufficiently describe the dynamics of given plant and purposes for which model is build.

All linear models can be derived from general linear model (Ljung, 1987) by its simplification. In this work, the three basic linear models are taken into consideration. These are ARX, ARMAX, OE models.

These models are used in identification part of STC for description of the dynamics of given plant.

3. RECURSIVE PARAMETER ESTIMATION

Recursive identification algorithm is an integral part of STC and play important role in tracking time-variant parameters. The recursive parameter estimation algorithms are based on the data analysis of the input and output signals from the process to be identified. Many recursive identification algorithms were proposed (Ljung, 1987, Soderstrom & Stoica 1989; Wellstead & Zarrop 1991; Nelles 2001). In this part several well-known recursive algorithms with forgetting factors are briefly summarized.

3.1 RLS

This method can be used for parameter estimate of ARX model. Standard RLS algorithm assumes that the parameters of the model process are constant. In many cases, however, the estimator will be required to track changes in a set of parameters.

To cope with tracking the time-variant parameters some adjustment mechanism must be introduced in the basic equations. Several implementations have been proposed (Kulhavy, 1987; Ljung, 1987; Soderstrom & Stoica 1989; Kulhavy & Zarrop 1993; Corriou, 2004; Wellstead & Zarrop 1991). In this work, fixed exponential forgetting, variable exponential forgetting and adaptive directional forgetting are taken into consideration.

3.2 RIV

It can be shown that if the process does not meet the noise assumption made by the ARX model, the parameters are estimated biased and nonconsistent. This problem can be avoided using instrumental variable method (Soderstrom & Stoica, 1989).

3.3 ERIV

This method ensures improved accuracy and greater speed of convergence than RIV. The method is based on choice of instruments vector which has more elements than there are parameters in the model to be estimated. Derivation of this algorithm can be found in (Soderstrom & Stoica 1989). Instruments can be chosen according to (Branica et. al., 1996; Soderstrom & Stoica 1989).

3.4 RELS

This method is used for parameter estimations of ARMAX model. Formally it takes the same form as RLS. However, the regression and parameter vectors are different

3.5 RPEM

The recursive prediction error method (RPEM) allows the online identification of all linear model structure. Since all model structure except ARX are nonlinearly parameterized, no exact recursive algorithm can exist; rather some approximations must be made (Moore & Boel 1986; Moore & Weiss 1979; Soderstrom & Stoica 1989).

4. SIMULATION

The recursive identification algorithms mentioned above were tested in closed loop on system given by continuous-time transfer function (1) with self-tuning LQ controller. The controller is based on minimization of quadratic criterion with controller output signal penalization. The minimization of quadratic criterion is realized by spectral factorization.

G(s) = s+1/50[s.sub.2] + 15s+1, t [less than or equal to]s

G(s) = s + 1,5/50[s.sup.2] + 15s + 1, t [greater than or equal to]s (1)

The block diagram of controlled system is shown in Fig. 1. It can be seen that the system output is directly influenced by non-measurable disturbance. This case is commonly fulfilled in practice.

[FIGURE 1 OMITTED]

The sampling period was chosen [T.sub.0] = 4s.

The same initial conditions for system identification were used for all the types of recursive algorithms we tested. The initial parameter estimates for ARX, ARMAX, OE model were chosen to be zero.

Estimation algorithms with fixed and variable exponential forgetting (FEF, VEF) were applied using a forgetting factor [lambda](0) = 0.985. Initial values for adaptive forgetting (ADF) were chosen to be [phi](0) = 1, [rho](0) = 0.99, v(0) = [10.sup.-6], [lambda](0) = 0.001. System dynamics were described by ARX, OE, ARMAX model, respectively. Parameters of ARX model were identified by RLS, RIV and ERIV methods, RELS and RPEM methods were used to parameter estimation of ARMAX model and parameters of OE model were estimated by RPEM method. To assure parameters tracking the forgetting factors were used. Only parameters of deterministic part of the estimated models were utilized for controller synthesis. Influence of each recursive algorithms on adaptive control performance were evaluated from quality control point of view. The results can be seen in Table 1. The criteria were defined

[MATHEMATICAL EXPRESSION NOT REPRODUCIBLE IN ASCII] (2)

[MATHEMATICAL EXPRESSION NOT REPRODUCIBLE IN ASCII] (3)

where e(k) denotes control error, u(k) is controller output and [k.sub.1] = 1, [k.sub.2] = 500.

From Table 1 can be seen that the minimum of sum of squared control error and minimum of sum of squared difference of controller output signal were achieved by RIV method with adaptive directional forgetting for parameter estimate of ARX model. Other methods listed in Table 1 also provide satisfactory results except RLS with variable exponential forgetting.

5. CONCLUSION

The recursive estimation algorithms were reviewed and applied to estimate ARX, ARMAX, OE model under closed loop control. In some cases, the recursive least squares method leads to inadequate estimations and the controller based on these estimated parameters can give poor performance. From simulation results can be concluded that the recursive identification methods presented here provided superior parameter estimates. This is the condition for improvement reliability of algorithms in adaptive control systems.

6. ACKNOWLEDGEMENT

The work has been supported in part by the Grant Agency of the Czech Republic under grants No. 102/05/0271, 102/03/0070 and by the Ministry of Education of the Czech Republic under grant MSM7088352101.

7. REFERENCES

Bobal, V.; J. Bohm & Prokop, R. (1999). Practical Aspects of Self-Tuning Controllers. International Journal of Adaptive Control and Signal Processing, 13, pp. 671-690.

Bobal, V., Bohm, J.; Fessl, J. & Machacek, J. (2005). Digital Self-tuning Controllers: Algorithms, Implementation and Applications. Springer-Verlag, London.

Branica, I., N. Peric & Petrovic, I. (1996). Comparison of Several Recursive Identification Methods. Automatika,Vol. 37, No. 3-4, pp. 99-104.

Corriou, J. P. (2004). Process Control : Theory and Applications. Springer-Verlag, London.

Kulhavy, R. (1987). Restricted exponential forgetting in real time identification. Automatica, Vol. 23, pp. 586-600.

Kulhavy, R. & Zarrop, M.B. (1993). On a general concept of forgetting. International Journal of Control, 58, 4: pp. 905-924.

Ljung, L. (1987). System identification--theory for user. Prentice-Hall, Englewood Cliffs, N.J.

Moore, J. B. & Boel, R. K. (1986). Asymptotically Optimum Recursive Prediction Error Methods in Adaptive Estimation and Control. Automatica, Vol. 22, No. 2, pp. 237-240.

Moore, J. B. & Weiss, H. (1979). Recursive Prediction Error Methods for Adaptive Estimation. IEEE Trans. on Systems, Man, and Cybernetics. Vol. SMC-9, No. 4, pp. 197-205.

Nelles, O. (2001). Nonlinear system identification. Springer-Verlag. Berlin.

Soderstrom, T. & Stoica, P. (1989). System Identification. Prentice Hall, University Press, Cambridge, UK.

Wellstead, P.E. & Zarrop, M.B. (1991). Self-Tuning System--Control and Signal Processing, John Wiley & Sons Ltd. Chichester.

Table 1. Simulation results: Control quality

Method	[S.sub.y]	[S.sub.y]
RLS with VEF	0.0460	0.0429
RLS with ADF	0.0054	0.0146
ERIV with FEF	0.0404	0.0276
RIV with ADF	0.0025	0.0126
RPEM-ARMAX with FEF	0.0027	0.0205
RELS with ADF	0.0058	0.0207
RPEM-OE with FEF	0.0026	0.0294

Article Details

Printer friendly Cite/link Email Feedback

Author: Navratil, P.; Bobal, V.
Publication: Annals of DAAAM & Proceedings
Article Type: Report
Geographic Code: 4EUUK
Date: Jan 1, 2005
Words: 1599
Previous Article: One of possible approaches to solution of autonomy and invariance of MIMO systems.
Next Article: Methods of determination of wormwheel tooth surface.
Topics: Linear systems
Models
Parameter estimation
Methods
Recursive functions
Usage