ON-LINE IDENTIFICATION WITH THE SELECTION OF TRAINING PATTERNS FOR THE SELF-TUNING CONTROLLERS

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ABSTRACT

This paper describes the principle of the adaptive controller with identification based on the artificial neural network. The novel method for training pattern selection is presented. This method uses the computing of distances between all training patterns. Presented algorithm improves the performance and stability of the identification. Behavior of described algorithm is presented using the simulation experiments.

1 INTRODUCTION

The purpose of adaptive controllers is to adapt parameters of control law to changes of the controlled system. Many types of adaptive controllers are known. The adaptive self-tuning LQ controller is described in this article. The scheme of this controller is separated into two main parts: identification and controller [3, 5]. In this work, identification based on neural network approach is used. The linear quadratic optimal controller is used as the control algorithm. Figure 1 shows the architecture of the self-tuning LQ controller where *w* denotes desired value, *u* denotes action value and *y* denotes output of the controlled system.

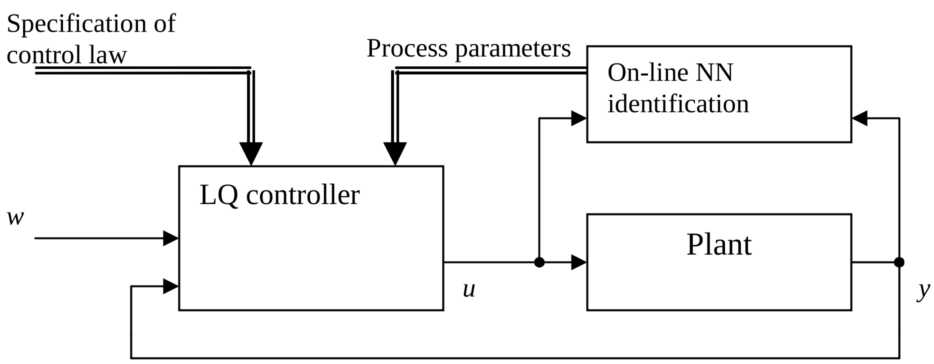

Figure 1: Architecture of self-tuning LQ controller.

2 ON-LINE IDENTIFICATION

The most important part of self-tuning systems is the on-line identification algorithm. The recursive least squares method (RLS) is widely used method for system identification [3]. Instead of RLS, the identification method based on neural network can be used. A very fast algorithm for training neural networks is the Levenberg-Marquardt (LM) algorithm [1]. The main idea of on-line identification is that according to the measured input to the identified system $u(t)$ and the corresponding system output $y(t)$ we are able to find the vector of system parameters Θ.

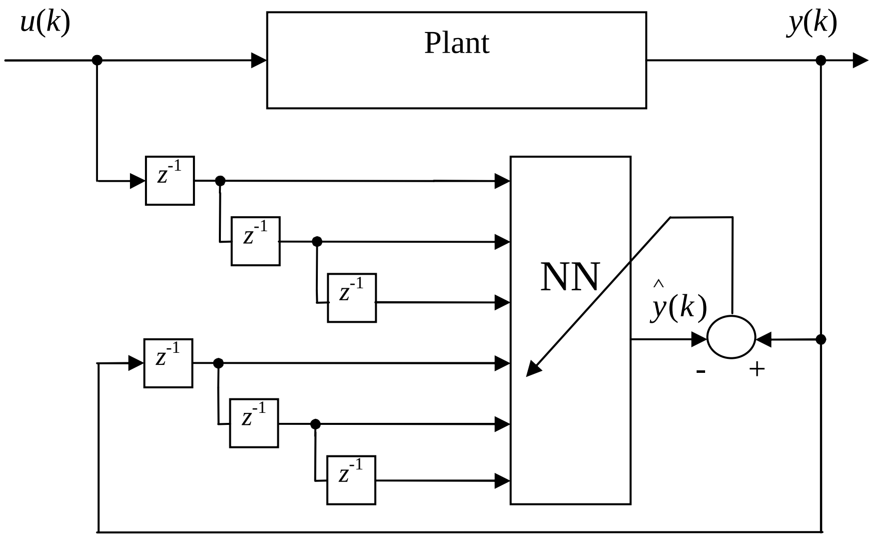

Figure 2: The principle of identification of system using neural network.

For computing the identified system output we can use the linear ARX model

$$F_M(z^{-1}) = \frac{b_1 z^{-1} + b_2 z^{-2} + b_3 z^{-3}}{1 + a_1 z^{-1} + a_2 z^{-2} + a_3 z^{-3}} \quad (1)$$

The ARX model can be written in vector form as follows

$$\hat{y}(k) = \varphi^T(k)\theta(k) \quad (2)$$

where

$$\varphi(k) = [u(k-1)\ \ldots\ u(k-1-m) - y(k-1)\ \ldots\ -y(k-1-n)]^T \quad (3)$$

is the vector of measured inputs and outputs and

$$\theta(k) = [b_1(k)\ \ldots\ b_m(k)\ a_1(k)\ \ldots\ a_n(k)]^T \quad (4)$$

is the vector of estimated system parameters.

As it has been mentioned above, the Levenberg–Marquardt method can be used for training of the neural network. The new vector of parameters is in each step given by next equation.

$$\theta(k+1)=\theta(k)-\left(JJ^T+\lambda I\right)^{-1}J^T\varepsilon(k) \qquad (5)$$

where J is Jacobian matrix in form

$$J=\begin{pmatrix} \frac{\partial\varepsilon_1}{\partial w_1} & \cdots & \frac{\partial\varepsilon_1}{\partial w_j} \\ \vdots & \ddots & \vdots \\ \frac{\partial\varepsilon_p}{\partial w_1} & \cdots & \frac{\partial\varepsilon_p}{\partial w_j} \end{pmatrix} \qquad (6)$$

and ε is the vector of errors between the output of the system and the output of the model for all training patterns. The parameter p is the number of training patterns and j is the number of estimated parameters.

3 CREATION OF THE TRAINING SET

Training of the neural networks is performing with the all training patterns in the training set. If the on-line identification is used, we have the new training pattern in the each sampling time. Because of the limited number of elements in the training set we have to eliminate the old element in the same step. Classical concept is to take into account only the age of the patterns. That means the oldest training pattern is eliminated in each step. This method could be the cause of bad behavior of identification in the cases when the identified system is not persistently excited [6].

In [1] was designed more sophisticated algorithm for elimination of training patterns. This algorithm can be described as follows:

1. Measure a new pattern.
2. If the training set contains a maximum number of patterns,
   a) Find in the training set two nearest patterns.
   b) Remove the older one.
3. Add a new pattern to the training set.

The distance between two patterns (input vectors of the neural network) can be computed using transformation R which transforms input vector φ to the new space:

$$\varphi' = R\varphi. \qquad (7)$$

Then the distance between two vectors is defined as follows:

$$\left\|\varphi_i'-\varphi_j'\right\|=\left\|R\varphi_i-R\varphi_j\right\|=\left\|R\Delta\varphi\right\|=\sqrt{\Delta\varphi^T R^T R\Delta\varphi}\,, \qquad (8)$$

where expression $R^T R$ is the transformation matrix. In the basic case it can be equal to the identity matrix.

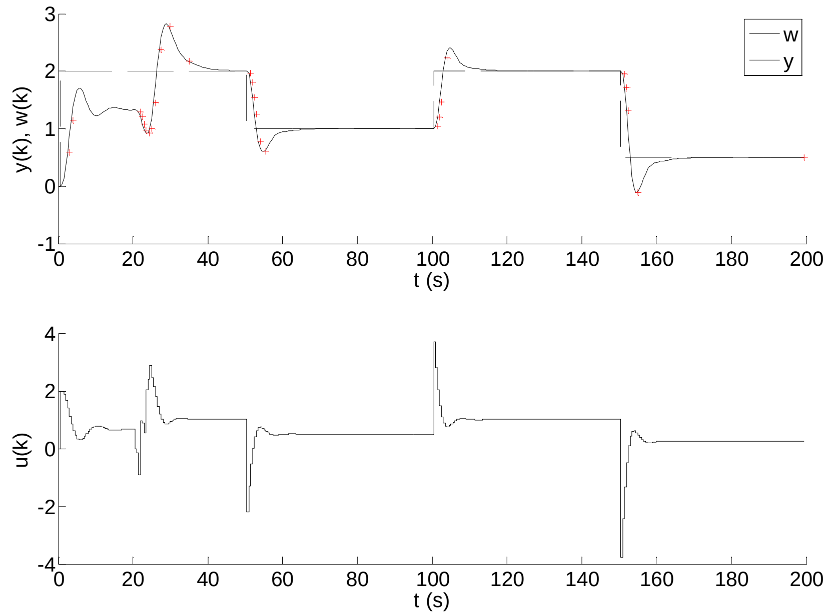

Figure 3: Chosen training patterns (+) after time 200 seconds.

Figure 3 shows training patterns chosen by described algorithm. One can see that to the training set wasn't included data from the steady states.

Next improvement of this algorithm can be reached by penalization of oldest patterns. All distances between patterns are multiplied by variable γ defined as follows:

$$\gamma = e^{(1-\lambda)\max(t_1, t_2)}, \qquad (9)$$

where t_1 and t_2 denote the age of two training patterns which are compared.

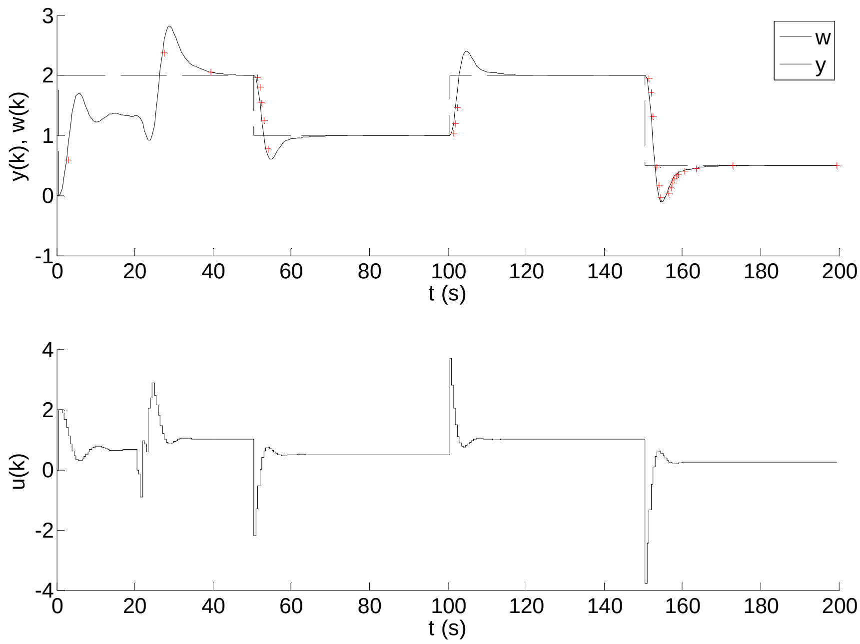

Figure 4: Chosen training patterns (+) after time 200 seconds with the time penalization.

One can see that time penalization leads to training set that contains newest patterns. It is obvious that novel algorithm with time penalization is able to faster adaptation to changes of the identified system.

4 CONCLUSION

The article shows the method for creating training set for on-line neural network identification. This method is based on the computing of distances between all training patterns. The main idea of this algorithm is to increase useful differences in the training set for purpose of improvement of stability and adaptability of identification algorithm. The novel algorithm for training patterns selection with the time penalization extends the algorithm which was introduced in [1]. Result of described method was shown on the simulation experiments using the MATLAB/Simulink environment.

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