

Passive Identification is Non Stationary Objects With Closed Loop Control

Valeriy F Dyadik¹, Igor S Nadezhdin¹, Alexey G Goryunov¹, Flavio Manenti²

¹Tomsk Polytechnic University, Institute of Physics and Technology, Department of Electronics and Automation of Nuclear Plants, Russia, Tomsk, Lenina St 30, 634050

²Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica «Giulio Natta» Italy, Milano, Piazza Leonardo da Vinci 32, 20133

E-mail: kun9@list.ru

Abstract. Typically chemical processes have significant nonlinear dynamics, but despite this, industry is conventionally still using PID-based regulatory control systems. Moreover, process units are interconnected, in terms of inlet and outlet material/energy flows, to other neighbouring units, thus their dynamic behaviour is strongly influenced by these connections and, as a consequence, conventional control systems performance often proves to be poor. However, there a hybrid fuzzy PID control logic, whose tuning parameters are provided in real time. The fuzzy controller tuning is made on the basis of Mamdani controller, also exploiting the results coming from an identification procedure that is carried on when an unmeasured step disturbance of any shape affects the process behaviour. This paper presents procedure for identifying technological object control in a closed loop, i. e. that operates the automated control system. The variation in the controlled variable, caused by the change of the non-measurable disturbance, is considered the initial signal for the identification procedure. The parameters of the control object are found by optimization method Levenberg-Marquardt.

1. Introduction

Nowadays, in chemical and nuclear industries (i.e. integrated separations, extractions crystallization processes to purify U and Pu from other fusion side-components) any processing step has a high level of automation. On the one hand, all processes are high responsibility technology (HRT), i.e. high performance technology with respect of safety level. On the other hand, they are also complex dynamic systems. Experience shows that the usually the conventional PID controller is not effective for complex dynamic systems [1]. A number of researchers have conducted studies to develop a hybrid fuzzy PID control logic, whose tuning parameters are provided in real time. The fuzzy controller tuning is made on the basis of Mamdani controller, also exploiting the results coming from an identification procedure. The problem of identifying has attracted and attracts a lot of research interests and many methods are available for this problem in literature [2].

A priori information about the dynamics of the controlled plant is required for the synthesis of PID-based fuzzy logic controller. Hammerstein and Wiener models may be used to describe complex dynamics real-life processes [3, 4]. Hammerstein and Wiener models are methodologies constituted by the combination of a static nonlinearity (N) and a linear system (L), respectively in the N-L and L-N



form. The problem of identifying N and L from input-output data has attracted and attracts a lot of research interests and many methods are available for this problem in literature [5]. The nonlinear dynamic system can be approximated by a linear dynamic system near the operating point, which is sufficient for PID tuning. It is not a simple task to define the parameters of the linear dynamic model approximation in the closed-loop system. In [6, 7] active methods of identification are proposed; here sine waves in input are used to excite the Wiener continuous-time system and frequency methods are used to determine the unknowns. Unknown additive disturbances create problems for closed-loop identification. Good results can be obtained by using MATLAB system identification toolbox for the identification of the parameters of the process with the use of ARX, ARMAX, BJ state space, polynomial models and others [8].

2. Material and methods for passive identification

The proposed method employs algorithms for the plant identification coupled with fuzzy systems such as Mamdani controllers [9]. The layout of a generic automatic control systems plant is presented in Fig. 1 while a scheme of an adaptive fuzzy controller is shown in Fig. 2.

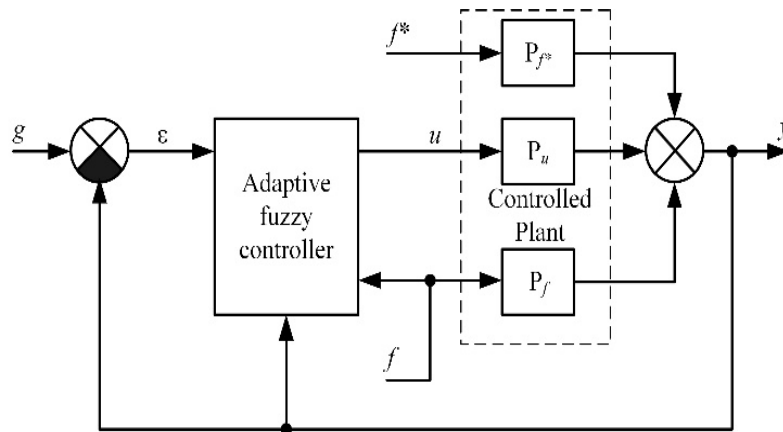


Figure 1. Fuzzy adaptive control system. g : reference signal; f^* : non-measurable disturbance; f : measurable disturbance; P_u : plant control channel; P_f : plant disturbance channel; P_{f^*} : plant non-measurable disturbance channel; y : controlled variable; ε : control error is defined as $\varepsilon = g - y$.

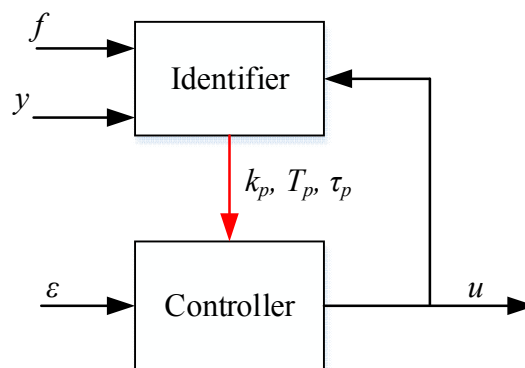


Figure 2. Adaptive fuzzy controller for automatic control systems.

The operating principle of identifier (Fig. 2), is shown in Figure 3. In this paper use the step disturbance variables, but is not known value and duration of these disturbances.

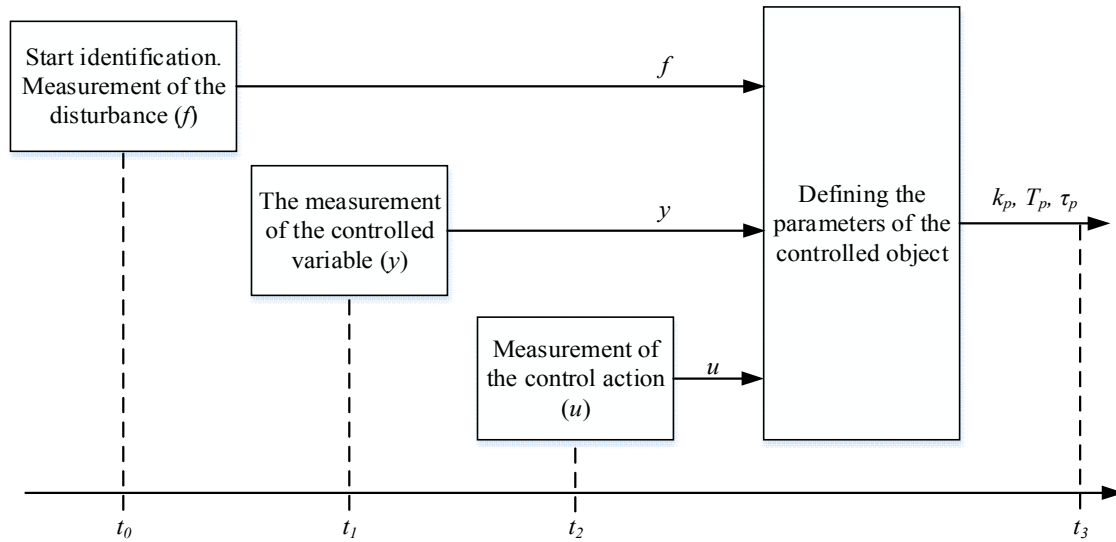


Figure 3. The principle of operation identifier.

The identification is performed in the closed-loop system in those operating conditions where the edge of the transient is reached (see Fig. 4).

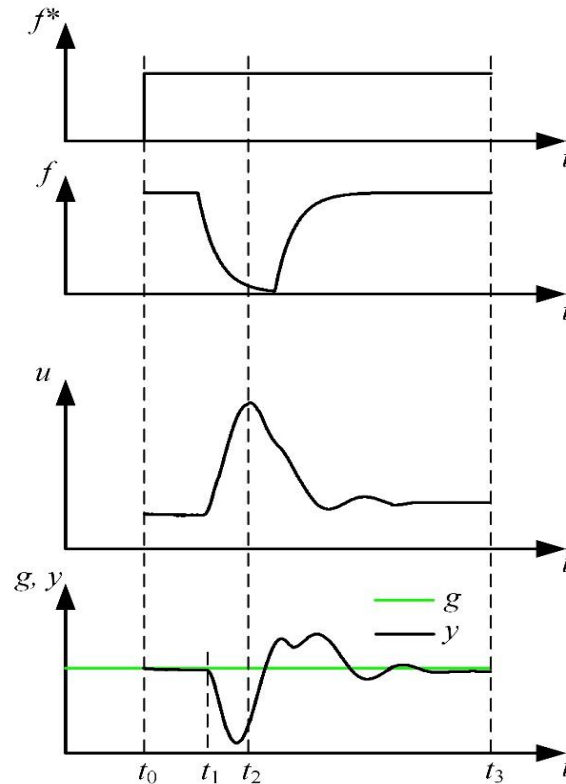


Figure 4. Transient of the automatic control systems for the identification of plant parameters in a closed loop.

The variation in the controlled variable, caused by the change of the non-measurable disturbance f^* , is considered the initial signal for the identification procedure. The time instant t_0 where the non-measurable step disturbance f^* undergoes a step change is unknown. The time instant t_1 is defined by the deviation threshold of y from g by $\Delta y > y_g$, where y_g is the required control accuracy, and t_2 is the time instant of the y variable sign change. The parameters of the plant are defined by Levenberg-Marquardt optimization method. In this case, the measured disturbance f , the control action u and the controlled variable y (see Fig. 1 – 4) are supplied to the identifier input in the time interval whose lower and upper bounds are, respectively, t_2 and t_3 . The parameters of the plant (k_p , T_p , τ_p) and those related to the disturbance (k_p^f , T_p^f , τ_p^f) are optimized, in accordance with the reported statements, by the iterative prediction-error estimation method (pem) by Matlab:

$$\begin{cases} y_j^m = y_j^u(u_j, k_p, T_p, \tau_p) + y_j^f(f_j, k_p^f, T_p^f, \tau_p^f) \\ S = \sqrt{\sum_{j=1}^n (y_j^m - y_j)^2 / (n-1)} \\ S \rightarrow 0 \end{cases} \quad (1)$$

where y_j^u , y_j^f are a digital representation of the plant model with lagging for channels u and f , S is the optimized functional, n is the dimension of access. The dynamics of the plant is described as a linear system with the transfer function $W_p^u(s)$ that represents channel u and the transfer function $W_p^f(s)$ that stand for channel f :

$$W_p^u(s) = \frac{k_p}{T_p \cdot s + 1} \cdot e^{-\tau_p s}, \quad W_p^f(s) = \frac{k_p^f}{T_p^f \cdot s + 1} \cdot e^{-\tau_p^f s} \quad (2)$$

3. Results of the passive identification with closed loop control

The proposed the procedure for identifying controlled object was used in the identifier, which is used in the development of automated control system with fuzzy logic. The identifier and the automatic control system was are implemented in the package MATLAB/Simulink.

Realized identifier makes determination of the parameters of the transfer functions of the control object on control and disturbance (2). Table 1 shows the results of identification of parameters of control object after making the system disturbances. Into the system was introduced a step disturbance with unknown characteristics.

Table 1. The results of the identification.

Object parameters	The parameter values of the transfer function of the object		The results of the identification	
	Control	The perturbation	Control	The perturbation
k_p	4.3	4	4.7	4.4
T_{p1}	90	90	107.8	107.1
T_{p2}	25	-	-	-
T_{p3}	2.5	-	-	-
τ_p	12	30	62.6	26

The controlled object is represented transfer function the third order. As a result, the identification of the control object was described by the transfer function of the first order with delay. The discrepancy of transient processes after identification was 0.3%, the transient processes are presented in Fig. 5.

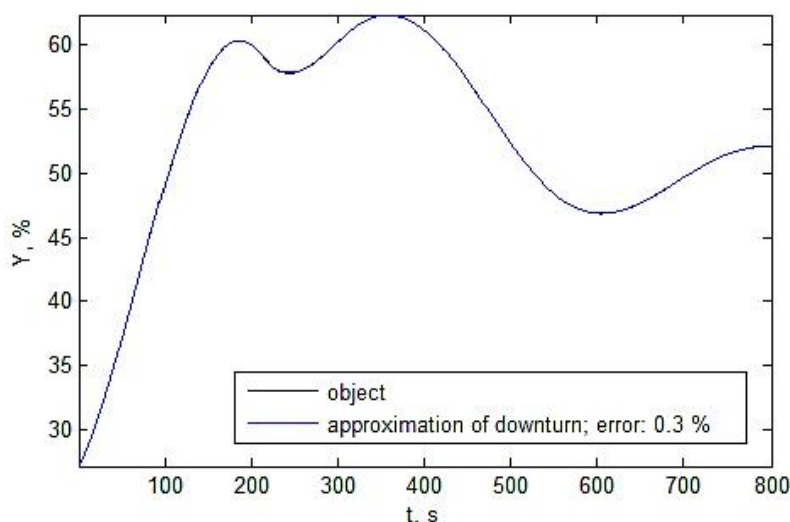


Figure 5. The transition process ("the downturn", after the impact of the disturbance) for the identification parameters of the controlled object

It was also investigated the work identifier at entering the system step disturbances with noise. As the noise interference used additive white Gaussian noise. The results of identification are shown in Table 2.

Table 2. The results of the identification.

Object parameters	The parameter values of the transfer function of the object		The results of the identification	
	Control	The perturbation	Control	The perturbation
k_p	4.3	4	10	8.6
T_{p1}	90	90	239.3	241.7
T_{p2}	25	-	-	-
T_{p3}	2.5	-	-	-
τ_p	12	30	41.8	28.3

Fig. 6 shows the transition process that indicate that an error in the identification of 1.2 %.

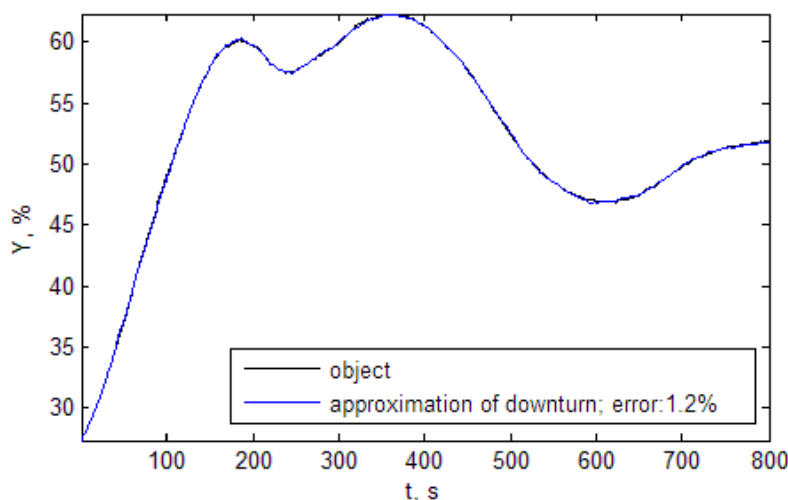


Figure 6. The transition process ("the downturn", after the impact of the disturbance with noise) for the identification parameters of the controlled object

The use of white noise explained by its wide distribution in nature and technology. In practice, most of the signals contain the noise. The use for research step disturbance with noise, will allow more realistically simulate the identification procedure. As seen from the transient processes, the proposed identifier performs its functions, even at disturbance with noise.

4. Conclusions

As a result of the work was implemented identifier in structure of system control with fuzzy logic. The work was performed in the package MATLAB/Simulink. Identification of the parameters of the control object is carried out in a closed loop, with step disturbances of unknown magnitude and duration. Error occurred while identify the parameters of the object was 0.3 %. In studying of the proposed procedures the identification, on the disturbance was superimposed noise. As the interference was used additive white Gaussian noise. Error occurred while identification of parameters of the object at step disturbance with white noise was 1.2 %. The results demonstrate the possibility of determining the parameters of the object in a closed loop, using the proposed identification procedure.

5. Acknowledgements

This work was funded as part of the Federal government-sponsored program «Science» by Tomsk Polytechnic University.

References

- [1] Gao Z., Kong D., Gao C., Chen M. 2013. Modeling and control of complex dynamic systems. *Journal of Applied Mathematics*. Article number 151372. DOI: 10.1155/2012/869792
- [2] Ikhoulane F., Giri F. 2014. A unified approach for the parametric identification of SISO/MIMO Wiener and Hammerstein systems. *Journal of the Franklin Institute*. 351(3) 1717–27.
- [3] Biagiola S.I., Figueroa J.L. 2009. Wiener and Hammerstein uncertain models identification. *Mathematics and Computers in Simulation*. 79(11) 3296–313.
- [4] Dempsey E.J., Westwick D.T. 2004. Identification of Hammerstein models with cubic spline nonlinearities. *IEEE Transactions on Biomedical Engineering*. 51(2) 237–45.
- [5] Zhou L., Li X., Pan F. 2013. Gradient based iterative parameter identification for Wiener nonlinear systems. *Applied Mathematical Modelling*. 37(16-17) 8203–09.
- [6] Giri F., Rochdi Y., Chaoui F.Z. 2009. An analytic geometry approach to wiener system frequency identification. *IEEE Transactions on Automatic Control*. 54(4) 683–96.
- [7] Giri F., Rochdi Y., Radouane A., Brouri A., Chaoui F.Z. 2013. Frequency identification of

- nonparametric Wiener systems containing backlash nonlinearities. *Automatica*. 49(1) 124–37.
- [8] Rabbani M.J., Hussain K., Khan A.U.R., Ali A. 2013. Model identification and validation for a heating system using Matlab system identification toolbox. In: Proceedings of the 1st International Conference on Sensing for Industry, Control, Communications, and Security Technologies, ICSICCST 2013, Karachi, Pakistan: June 2013. IOP Conference Series: Materials Science and Engineering. 51(1) DOI: 10.1088/1757-899X/51/1/012022.
- [9] Xu X.Q. 2014. The application of MATLAB for fuzzy control system simulation. *Applied Mechanics and Materials*. 494-495 1306–9.