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P-ILC for Output Data Dropouts and its Application in Wastewater Biological Treatment Plant

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Abstract: this study in order to efficiency of sewage treatment, construct P-ILC algorithm for output data dropouts. The P-ILC algorithm is used in the aeration tank of oxygen input link, considering the data generating omissions, adjusting the algorithm can completely control the aeration tank of oxygen. After 20 iterations, we can completely control the oxygen in the aeration tank volume. The more important is that algorithm can adjust the oxygen content at any time according to the need of aeration tank, when the lack of oxygen, can open the oxygen filling pump, when sufficient oxygen, close the oxygen filling pump, to achieve energy saving goals, ultimately makes the economic benefits to achieve the highest.

Key words: Iterative learning control, output data, data dropouts, wastewater treatment process, simulation

INTRODUCTION

Water resource including the human control and surface water and groundwater directly for irrigation, power generation, water supply, shipping, aquaculture and other purposes, as well as the rivers, lakes, wells, springs, tidal, harbor and water area. Water resources are important natural resources indispensable for the development of the national economy. With the development of the world economy, population growth, increasing and expanding around the city, with water rising.

The United Nations estimates, in 1900, the global water consumption is only 4×10^{11} m^3 year^{-1}, 1980 is 3×10^{12} m^3 year^{-1}, 1985 is 3.9×10^{12} m^3 year^{-1}. It is expected that by 2000, demand will increase to 6×10^{12} m^3 year^{-1}. In Asia with the most water, up to 3.2×10^{12} m^3 year^{-1}, followed by North America, Europe, South America etc. With the development of production, the contradiction between supply and demand of regional and national water resource is increasingly prominent. Along with sewage reuse problem has become a topic of concern. According to the classification of the source of wastewater, wastewater treatment is generally divided into the production of Production sewage and living sewage. Production sewage including: Industrial wastewater, agricultural wastewater and medical sewage. living sewage is sewage generated daily life, is a complicated mixture, refers to various forms of inorganic and organic include: The size of solid particles of floating and suspended; gel and gel diffusion in pure solution. Water pollution according to the different pollution of impurities is: Chemical pollution, physical pollution and biological pollution three categories. The main pollutants are: the industrial wastewater discharge of untreated, the extensive use of fertilizers, pesticides, herbicides farmland sewage, the stacked in the industrial waste and domestic waste Sewage treatment methods can be summarized as physical method, chemical method and biological method (Bongards and Ebel Hilmer, 2004). This study focuses on city life sewage biological treatment in two stage aeration tank Dissolved Oxygen (DO) concentration. For the DO process control, including PID control, adaptive control, nonlinear control, has a large number of papers published. In recent years, the research of fuzzy control and neural network control in intelligent control to stabilize the DO value, provides some deal with the nonlinear and uncertain means and methods of process Ferrer *et al.* (1998) and Punal *et al.* (2002) describes the control process of the mould for biological wastewater treatment process modeling, control and optimization of fuzzy controller in 1998, control rule is obtained by summing up the operator's experience. Yu and Liaw proposed (Yu *et al.*, 1998) real-time control method for in 1998. (Punal *et al.*, 2002) developed a combination of fuzzy control and neural network control scheme in 2001 Punal *et al.* (2002) and Piotrowski *et al.* (2008) proposed the expert control system applied in sewage treatment in

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the case. (Bongards, 2001; Carrasco *et al.*, 2004), described in 2004 for the DO control based on another kind of neural network predictive control scheme (Piotrowski *et al.*, 2008).

RESEARCH METHOD

The time rate of change of concentration:

$$V\frac{dS_o}{dt} = Q_{in}S_{o,in} - Q_{out}S_o + VK_La(S_{o,out} - S_o) \quad (1)$$

where, V is the volume of aeration tank, It is measured in m^3, Q_{in} is the amount of water, Q_{out} is a water flow, It is measured in $m^3\ h^{-1}$, S_0 is the concentration of dissolved oxygen, It is measured in mg L^{-1}, $S_{o,in}$ is the concentration of dissolved oxygen in water,It is measured in mg L^{-1}, $S_{o,out}$ is the saturation of dissolved oxygen concentration, It is measured in mg L^{-1}, K_L is the absorption coefficient, a is the ratio of area and volume (On an open no aeration pool, its area refers to the area of contact of air and water, volume refers to the volume of the pool. In an aerated pond, the contact area with air and water of bubble size, bubble size is a function of aeration equipment and air flow), K_La for the dissolved oxygen mass transfer coefficient, It is measured in 1 h^{-1}. For a multiple input multiple output nonlinear system (Sun *et al.*, 2010):

$$\begin{cases} X_k(t+1) = F(x_k(t)) + B(x_k(t))U_k(t) \\ Y_k(t) = C(x_k(t)) + D(x_k(t))U_k(t) \end{cases} \quad (4)$$

where, k is the number of iterations, $X_k(t)$, $U_k(t)$, $Y_k(t)$ As the system state variables, system input variables and the output variable of the system. (Hatzikos *et al.*, 2003)

Hypothesis 1: The state variable $X_k(t)$ satisfies Lipschitz condition, The presence of A(X), B(X), C(X), D(X) such that for any time tÎ[0, N], we have matrix K_F, K_B, K_C, K_D, meet:

$$|F(X_1(t))-F(X_2(t))| \le K_F|X_1(t)-X_2(t)|$$

$$|B(X_1(t))-B(X_2(t))| \le K_B|X_1(t)-X_2(t)|$$

$$|C(X_1(t))-C(X_2(t))| \le K_C|X_1(t)-X_2(t)|$$

$$|D(X_1(t))-D(X_2(t))| \le K_D|X_1(t)-X_2(t)|$$

Hypothesis 2: The initial conditions for nonlinear systems of $X_k(0)$, $X_d(0)$ meet $X_k(0) = X_d$. Where $X_k(0)$ is the state variables in the k initial value, $X_d(0)$ is the initial expectation value.

Hypothesis 3: For the desired output for a given $Y_d(0)$, the control algorithm:

$$\begin{cases} X_d(t+1) = F(x_d(t)) + B(x_d(t))U_d(t) \\ Y_d(t) = C(x_d(t)) + D(x_d(t))U_d(t) \end{cases}$$

where, $X_d(t)$ and $U_d(t)$, respectively the desired output and the desired state.

For the linear system 1, the P type iterative learning control algorithm is as follows:

$$U_{k+1}(t) = U_k(t) + \eta\overline{E_k(t)} \quad (5)$$

where, η is the learning gain factor, $\overline{E_k(t)} = Y_d(t) - Y(t)$ as the system tracking error matrix, E{.} is the expected factor, $e_k(t) = E\{y_d(t)\}-y_k(t)$.

For iterative learning control in the control system, with possible data loss situation (Gu *et al.*, 2013) and data loss can be divided into $Y_d(t)$ output data loss and control input data loss of $U_k(t)$, main causes of $Y_d(t)$ data loss is due to the output signals from the sensor to the controller of the transfer process, the result of fault. For the $U_k(t)$ data loss, is the control input signal from controller to actuator transmission process caused by a fault, in order to facilitate the discussion, this study considers $U_k(t)$ data loss situation, a P type iterative learning control algorithm is constructed as follows:

$$U_{k+1}(t) = U_k(t) + G(t)\eta\overline{E}_k(t) \quad (6)$$

Where:

$$G(t) = \begin{bmatrix} g_1(t) \dots 0 \\ \ddots \\ 0 \dots g_r(t) \end{bmatrix}$$

Because of the randomness of data loss, G(t) and $U_k(t)$, $X_k(t)$, $Y_k(t)$ is irrelevant, assuming $P\{g_t(t) = 1\} = E\{g_t(t)\} = \bar{g}_t = 1, 2,..., r$.

For the sake of probability, P{.0}, E{.} as the expected factor, $\bar{g}$ for data transfer success rate and $0 \le \bar{g} \le 1$.

Theorem 1: To meet the assumptions of nonlinear system 2.2.1-2.2.3 (4), (5) the learning control algorithm is iterative, when the system output data loss, for the learning gain factor η on the number and all the time the t and iterative k, we have $\|I-\bar{g}\eta D(x_k(t))\|_\infty<1$.

For any t∈[0, N], we know that:

$$\lim_{k\to\infty} E\{y_k(t)\} \to y_d(t)$$

RESULTS AND ANALYSIS

According to the demand of aeration tank of oxygen quantity, we using P-ILC algorithm to control the oxygen quantity. The P-ILC algorithm is used in the aeration tank of oxygen input link, can with the aeration tank of oxygen demand is very good, according to the amount of oxygen aeration tank and decided to give the amount of oxygen aeration tank input and provide a theoretical basis for the energy saving our plan and ensure that the aeration tank of oxygen is sufficient, the sewage treatment the highest efficiency.

Each input oxygen process, given a desired oxygen demand y_d, looking for the control input $u_k(t)$, made in the control of the actual input amount of oxygen, y_{k+1} and y_d. Considering the possibility of the actual operation, it can be considered, demand control input selection of aeration tank of oxygen, each input to the aeration tank of oxygen process, when the amount of oxygen input oxygen demand set arrived immediately closed oxygen input valve, the amount of oxygen and the desired trajectory of the input (i.e., setpoint) exist error: $e_{k+1} = y_{k+1} - y_d$, Where k is the input oxygen number. Figure 1 describes the structure and process of ILC control method.

We use the simulation hypothesis:

$$\begin{bmatrix} X_1^{\bullet}(t) \\ X_2^{\bullet}(t) \end{bmatrix} = \begin{bmatrix} -2 & 3 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} X_1(t) \\ X_2(t) \end{bmatrix} + \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_1(t) \\ X_2(t) \end{bmatrix}$$

$$\begin{bmatrix} Y_1(t) \\ Y_2(t) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_1(t) \\ X_2(t) \end{bmatrix}$$

Oxygen demand expected in the aeration tank:

$$\begin{bmatrix} Y_{1d}(t) \\ Y_{2d}(t) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \sin(3t) \\ \cos(3t) \end{bmatrix} t \in [0, 1]$$

$$\bar{g}\eta = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}, \; D(x_k(t)) = \begin{bmatrix} 0.95 & 1 \\ 0 & 0.95 \end{bmatrix}$$

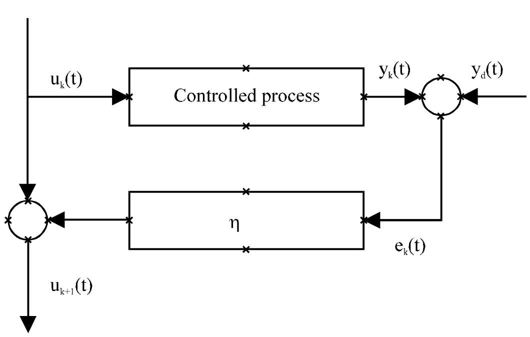

Fig. 1: Structure and process of ILC control method

For the initial state:

$$\begin{bmatrix} X_1^{\bullet}(0) \\ X_2^{\bullet}(0) \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

where, $X^{\bullet}_1(t)$ is the air contained in the amount of oxygen, $X^{\bullet}_2(t)$ is through the oxygen pump adding the amount of oxygen.

Figure 2 is a first and a second control input (the amount of oxygen aeration tank required), Fig. 3 for the twentieth iteration learning control algorithm tracking curve, we can see that after 20 iterations, the learning control, the target curve tracking, can completely control the number of oxygen in the aeration tank, this algorithm can control the oxygen effective. Figure 4 is the curve of

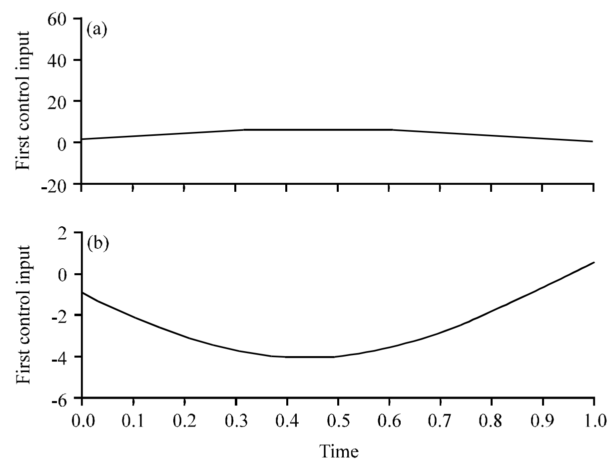

Fig. 2(a-b): First and second control input

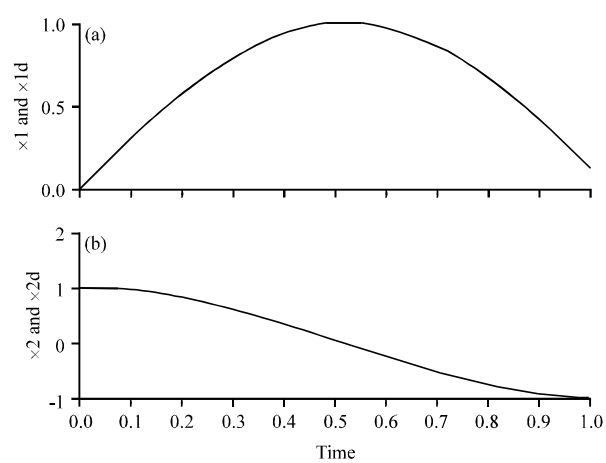

Fig. 3(a-b): The 20-th iterative learning control the tracking curve

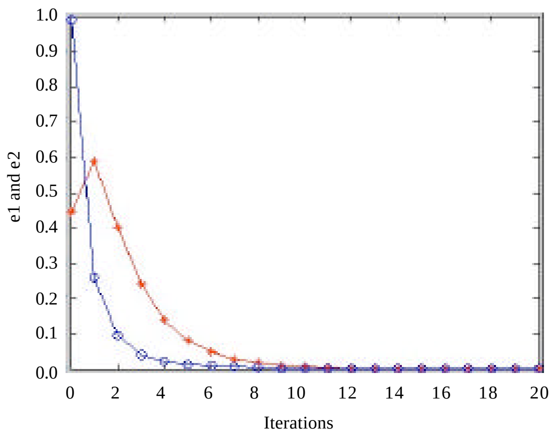

Fig. 4: log||e_k(t)|| convergence curve

error convergence curve, it can be seen that the algorithm will converge, the algorithm is proved to converge, the algorithm is reasonable.

CONCLUSION

- In order to make the sewage treatment efficiency is higher, the aeration tank of oxygen were analyzed and the P-ILC algorithm is used in the aeration tank of oxygen input link and according to the actual situation, considering the data generating omissions, adjusting the algorithm can completely control the aeration tank of oxygen
- Through the simulation experiment to validate the model and its corresponding algorithm, the results as shown in Fig. 5, shown in Fig. 6, not only can the aeration oxygen demand good tracking and can achieve perfect tracking oxygen demand goal after 20 regulation. More important is this algorithm may at any time according to need of aeration tank of oxygen supplement, when the lack of oxygen, can open the oxygen filling pump, when sufficient oxygen, close the oxygen filling pump, to achieve energy saving goals, ultimately makes the economic benefits to achieve the highest.

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REFERENCES

Bongards, M. and T. Ebel Hilmer, 2004. Predictive control of wastewater works by neural networks. Proceedings of the World Automation Congress, June 28-July 1, 2004, Seville, Spain, pp: 397-402.

Bongards, M., 2001. Improving the efficiency of a wastewater treatment plant by fuzzy control and neural network. Water Sci. Technol., 43: 189-196.

Carrasco, E.F., J. Rodriguez, A. Punal, E. Roca and J.M. Lema, 2004. Diagnosis of acidification states in an anaerobic wastewater treatment plant using a fuzzy-based expert system. Control Eng. Pract., 12: 59-64.

Ferrer, J., M.A. Rodrigo, A. Seco and J.M. Penya-roja, 1998. Energy saving in the aeration process by fuzzy logic control. Water Sci. Technol., 38: 209-217.

Gu, Q., X. Hao, X. Du, W. Xu and H. Li, 2013. Dynamic time warping distance algorithm application in iterative learning control. J. Comput. Inform. Syst., 9: 603-610.

Hatzikos, V.E., D.H. Owens and J. Hatonen, 2003. An evolutionary based optimization method for nonlinear iterative learning control systems. Proceedings of the American Control Conference, Volume 4, June 4-6, 2003, Denver, Colorado, pp: 3638-3643.

Piotrowski, R., M.A. Brdys, K. Konarczak, K. Duzinkiewicz and W. Chotkowski, 2008. Hierarchical dissolved oxygen control for activated sludge processes. Control Eng. Practice, 16: 114-131.

Punal, A., E. Roca and J.M. Lema, 2002. An expert system for monitoring and diagnosis of anaerobic wastewater treatment plants. Water Res., 36: 2656-2666.

Sun, M.X., D.W. Wang and P.N. Chen, 2010. Repetitive learning control of nonlinear systems over finite intervals. Sci. China Series F: Inform. Sci., 53: 115-128.

Yu, R.F., S.L. Liaw, C.N. Chang and W.Y. Cheng, 1998. Applying real-time control to enhance the performance of nitrogen removal in the continuous-flow SBR system. Water Sci., 38: 271-280.