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Optimal earth pressure balance control for shield tunneling based on LS-SVM and PSO

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ABSTRACT

To avoid ground deformation in the process of earth pressure balance (EPB) shield tunneling, it is necessary to keep the earth pressure balance on excavation face. However, at present the earth pressure control depends mainly on operation experiences which is hysteretic and could result in slow response to the change of earth pressure. To solve these problem, a predictive control strategy for earth pressure balance during excavation is proposed in this paper, where an earth pressure prediction model taking advance speed and screw conveyor speed as the control parameters is established by means of least squares support vector machine (LS-SVM). Further, by minimizing the difference between the predicted earth pressure and the desired one, an optimization model of the control parameters is established, and solved by the particle swarm optimization (PSO) algorithm. Therefore, an optimal EPB control scheme for shield tunneling automatically is presented here. The simulation results demonstrate that the method presented in this paper is very effective to control earth pressure balance.

1. Introduction

With the rapid development of urbanization, rational exploitation and utilization of the underground space is becoming an effective way to expand city capacity and functionality. Shield machine is an engineering machine specialized in excavating soft ground in underground construction engineer, and widely applied in tunnel, resources exploitation, and municipal construction and so on. To avoid accidents like surface subsidence during tunneling, the earth pressure on excavation face must be maintained balance.

To keep the earth pressure balance, the commonly used method is adjusting advance speed or screw conveyor speed [1], which depends mainly on the experiences of operator and is usually hysteretic. Consequently, it will cause some problems such as meandering routes, ground subsidence, and machine failure. To overcome these problems, some researchers have attempted to apply the intelligent control technology to shield tunneling construction. The fittingness of fuzzy control in shield tunneling process was first discussed [2], and then successfully used in shield automatic control and management during excavation [3]. The compound control of fuzzy control combined with a traditional proportion integration differentiation (PID) control that can compensate the closed-loop error and enhance the system performance, was applied to the complex and multivariable shield tunneling process [4]. In order to improve the dynamic response and stability of the simulation system, the fuzzy immune control method was applied to shield's earth pressure balance simulation system with delay, nonlinear and time-variable characteristics [5]. However, fuzzy control is usually based on expert knowledge, and difficult to examine all the input–output data recorded for the complex industrial process to adjust the rules and membership functions. The conventional automatic control methods like PID control need a long tuning time and are insufficiently robust. Although modern control theory such as optimal control or robust control theory seems to be an interesting alternative, they are based on accurate mathematical models which are hardly obtained for the complex process of shield tunneling.

Therefore, some researchers began to study the EPB control model for shield tunneling. Mitsutaka [6] proposed a model of the theoretical dynamic load acting on the shield during excavation, which taking into account the excavated area, the tail clearance, the rotation direction of the cutter face, sliding of the shield, ground loosening at the shield crown, and the dynamic equilibrium condition. Subsequently, to verify the model performance, the simulation of the shield behavior was carried out by applying the model of the loads acting on the shield to the shield tunneling work [7]. Shi [8] established an EPB control model with the real-time measured data by using the adaptive network-based fuzzy inference system. Due to the strong approximation ability of artificial neural networks to nonlinear system, the back propagation neural networks (BPNN)-based shield automatic control system was presented to balance earth pressure [9]. But as we all know, BPNN based on empirical risk minimization principle has some drawbacks in practical applications, such as slow convergence, easily immerging in local minimum, and network structure and type overdependence on experiences and so on.

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