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A Novel Approach to CNC Controller Parameter Optimization by Integrating Deep Learning Model with Particle Swarm Optimization

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Extended Abstract

In Computer numerical control (CNC) machine tool machining, the accuracy of the contour is highly affected by the interpolation and the servo control system. The interpolation parameters of CNC controller include the jerk constraint, acceleration/deceleration constants before and after interpolation, and the corner speed difference. The servo-control parameters consist of the feed rate, position loop gain and feedforward gain. The above parameters not only effect the contour error but also the machining time. Therefore, the optimal cost function is to minimize the machining time under the constraint of the given contour error tolerance. Most of research focused on optimizing the parameters such as feed rate and spindle speed to improve cutting efficiency [2]. Some studies searched for the better parameters based on engineering experiences without developing dynamic models [3]. These two approaches might not be able to obtain the optimal parameters with consideration of contour errors and machining time.

To achieve the objective of reducing the machining time under the contour errors tolerance, it is imperative to establish the models which are related the contour error and the machining time with system parameters. Some researches utilized the long short-term memory (LSTM) model to predict the real trajectory with the given interpolation points [4][5]. However, the time efficiency of these models might not be suitable to conduct the optimization process. Furthermore, the approach required the interpolation points as the inputs, rather than the CNC control parameters which might hinder the practical application. This paper utilizes the extreme gradient boosting (XGB) [6], back propagation neuron network (BPNN) [7] and Gaussian process regression (GPR) [8] to estimate the contour errors and machining time. To further improve the AI model accuracy for the contour errors, a region-partitioning method, based on the domain knowledge and correlation coefficients, is adopted. This approach segments regions with high variation of correlation coefficients between CNC parameters and contour error. Based on the simulation results, the GPR model could achieve the highest accuracy in contour errors, while the XGB model could obtain the highest accuracy on machining time. The contour error model achieved a maximum absolute error of 0.013 (mm) and an average absolute error of 0.001 (mm) on testing set. The machining time model reached a maximum absolute error of 0.02 (s) and average absolute error 0.002 (s). After developing the contour error and the machining time predicting model, the particle swarm optimization (PSO) [9] method is used to search the optimal parameters under the given contour error tolerance. A procedure to limit the range of variable parameters before the PSO optimization is adopted. The results validate that the optimization process could save up to10% in machining time under the given contour error tolerance equal to 0.03 (mm).

The contribution of this paper is to establish a controller parameter optimization framework which consists of three primary tasks: the GPR model for the contour error, the XGB model for the machining time, and the PSO process for controller parameter optimization. The results show that the proposed methodology enables optimal parameter computation for CNC parameter tuning with consideration of feed rate, interpolation and servo dynamics.

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