Position tracking control of an ultra-precision servo system

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Introduction

Ultra-precision positioning is a big challenge for cutting-edge manufacturing equipment. The shrinking nodes of VLSI domain tightened the performance requirements of those equipment. Achieving high tracking accuracy and anti-interference, a system heavily depends on controller design.

Difficulties exist at how to deal with the demands on high accuracy, usually nanometer level, as well as high speed, since the two factors sometimes work as contradiction to each other. In order to meet tightened specifications, mechatronic servo systems must extensively take the advantages of advanced control method [1][2]. Machine learning shows great benefit to deal with uncertainty and complexity. In order to achieve high positioning accuracy and get well along with dynamic disturbances during motions, an adaptive control method based on GA is proposed here below. Comparing to a system with traditional PID control method, the experimental results have shown a better tracking performance and a hundred-nanometers accuracy.

Novel control method

Consider a servo system shown in Fig. 1, G_C is the controller, G_P is the controller object, d is the dynamic disturbances, $y(t)$ is the actual output of the servo system, $r(t)$ is the desired output, then the tracking error of the system is defined by:

$$e(t) = r(t) - y(t), \quad (1)$$

where γ can be considered as velocity signals or position signals.

Refer to Eq. (1), the goal of the trajectory tracking control is:

$$\lim_{t=\forall} e(t) = 0, \quad (2)$$

Fig. 1. The control structure of a servo system.

It is hard to tune its parameters for a servo system performing optimally. As one of the widely used Machine learning methods, Genetic Algorithm (GA) is powerful to search for an optimal solution globally. A feedforward method based on GA is proposed here off-line optimization. Scripts simulate the operation of a servo system. Comparing the differences between the actual output and the desired trajectory, values of the parameters are updated during the GA training. The whole procedure has been presented in Fig.2 flow chart.

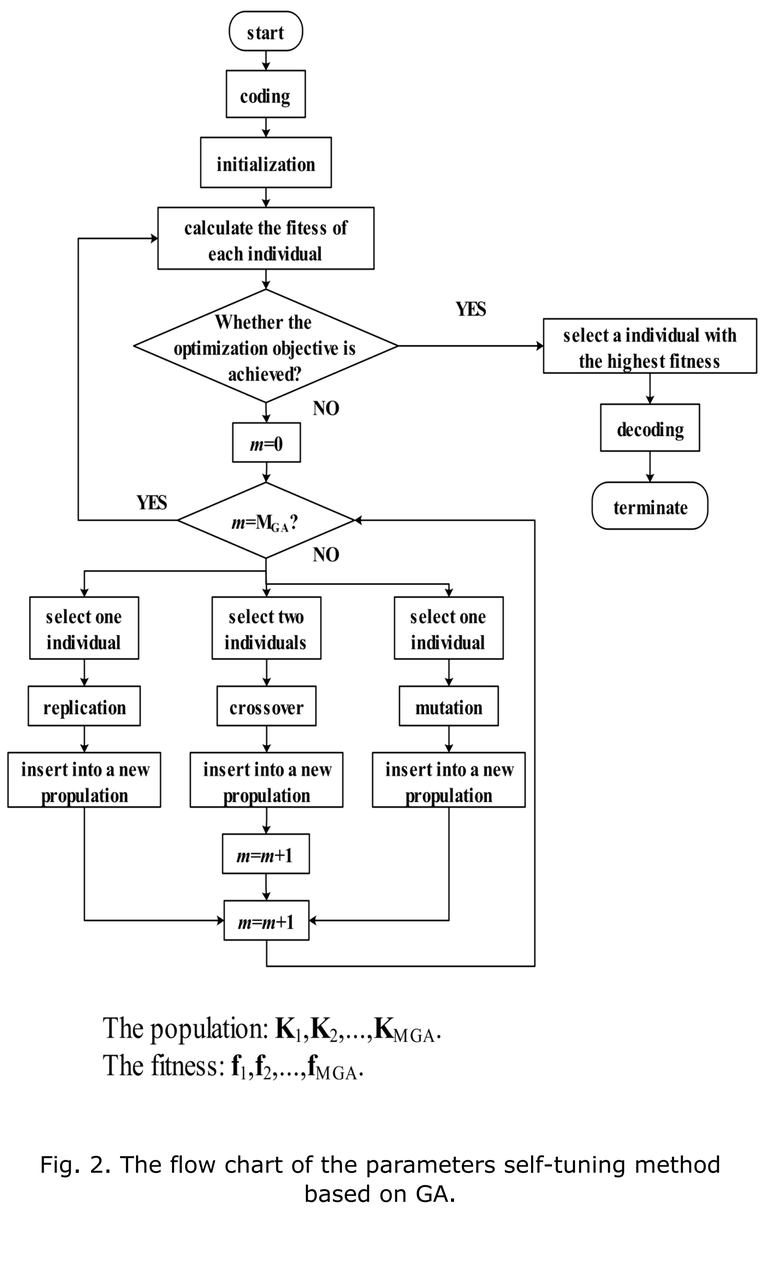
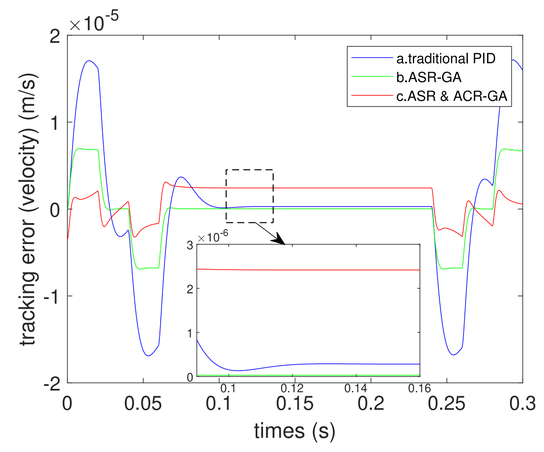


Fig. 2. The flow chart of the parameters self-tuning method based on GA.

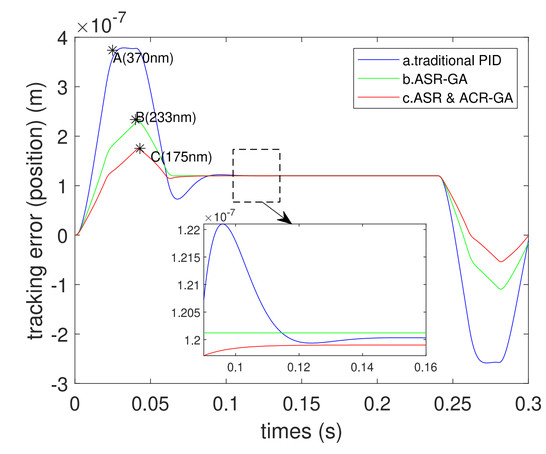
Results

In our experiments, s-curve is assumed as the trajectory and a Gaussian White noise has been added to our model. A typical motor model and its properties are selected to simulate the actuator of the high-end servo system.

As shown in Fig. 3, the tracking errors of all methods demonstrate the same trend. The velocity errors are reduced rapidly and changed smoothly when the parameters are tuned. The peak of the position tracking error is reduced by about 50%. From the magnification box, the proposed feedforward method via GA can reduce the position tracking error to a small region around hundred nanometers, which is less than that of system with the traditional PID method.



(a) The velocity error.



(b) The position error

Fig. 3. The tracking error of each axis with different methods

Conclusion

In this study, a control method based on GA has been proposed.

Based on the servo system model, the parameters of are obtained by GA training off-line. The first round experimental simulation has shown that the feedforward way can achieve about hundred-nanometers tracking accuracy and with the dynamic disturbances been restricted.

References

[1] Ziling Wang, Lai Zou, "Hybrid force/position control in workspace of robotic manipulator in uncertain environments based on adaptive fuzzy control". Robotics and Autonomous System, vol. 145, 2021.

[2] Gulshan Kumar, Nimai Pada Mandal, "Experimental study of position tracking control and pressure variation analysis on electrohydraulic system in open loop," Materials Today: Proceedings, vol. 56, pp. 2184-2188, 2022.

[3] M.F. Heertjes, H. Butler, "Control of Wafer Scanners: Methods and Developments" . American Control Conference. Denver, USA, July 1-3, 2020.

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