The AGPM Control Error Compensation Research

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Abstract. The article contraposed AGPM (Aspherical Grinding Polish Machine) control system, proposed an error prospective compensation method that based on the HM theory, combined threshold constraint technology and expectation evaluation ideas of statistics. Meanwhile, the corresponding control error compensation model was established. By experimental verification, the error compensation method can effectively solve the problem that error compensation of CNC, it also provided a new attempt for error compensation of NC system and its similar.

Introduction

At present, the machining efficiency and machining precision are the main reason which restrict aspheric optical parts widely application. The emergence of AGPM can solve the above problem in great extent [1~2], but, because of AGPM control system adopt the speed interpolation control theory, and instability error are produced by the speed interpolation compensation are difficult to implement. So, want to really make the AGPM solve the current problems existing in the aspheric surface machining, carried out error compensation research for AGPM control system is vital and no doubt.

The paper combined the HM theory in the field of pattern recognition and predictive error prediction ideas put forward a new method of error compensation, the theory is according to the error data of current and past, combining the HM theory, threshold constraint technology and expect evaluation thought established error prediction model, then, according to the model real-time prediction trajectory error for the future, and according to the error predicted value control the tool motion trajectory, so, the error will be corrected when is not effect.

The HMM Principle and Error Correction Model

The HMM (Hidden Markov Model) as a kind of statistical analysis Model, founded in the 1970s, obtained the spread development in the 1980s, and gradually become an important direction of the signal processing, has been successfully applied to natural voice processing [3], facial recognition [4], gait recognition [5~6], vehicle detection and tracking, etc.
The HMM principles

HMM is a parameterize, probability model of statistical properties that is used to describe random process, its status cannot be directly observed, but can be observed through the observation vector sequence, each observation vector is through certain probability density distribution of various states, each observation vector is the one who has a corresponding probability density distribution of state sequence is generated. So, HMM is a dual stochastic process, one is for the state has a certain number of hidden markov chain, the second to show the random function.

The error correction model

According to the actual error data was detected in the current and past trained the HMM, determine the basic elements of the HMM, specific steps as follows:

(1) The error data are processed by discretized. Divided "node" error into three kinds of state (high, normal, low) before the error correction in a particular threshold by T1; divided the "node" error into N kinds of observations in a particular threshold T2.

(2) HMM parameter estimation. Usually, when CNC machining the curve, divided it into N segments, after started processing of single period. So, according to the CNC machining theory will be curve is divided into N sections, establish N different HMM, and respectively correction.

(3) The error predicted. According to the error data of the past detection, the error values of processing the current time and the HMM, predict the possible error of the current time, gain access to the error prediction value e, the prediction error calculation formula:

\[ e_i = \tau_i \cdot p_i \] (1)

\[ \tau_i = S_{d-1}^i \cdot \zeta_i \] (2)

In the formula (1) (2), \( \tau_i \) is the prediction model probability distribution; \( p_i \) is the discretization distribution of the test error threshold T2; \( S_{d-1}^i \) is the probability of machining time at the same node model; \( \zeta_i \) is the probability distribution of state I transition to other state.

(4) The error compensation. Used to the calculated error compensated the actual error, gain access to the final CNC feeding.

The Error Compensation Realizing

The paper’s research object is AGPM, processed a curve feed 50 times get data for training model, before finishing 1 time the error value for testing data, establish the error compensation model, start the error predictive compensation. Selected relative error as the error evaluation, according to the error data of detection, determine the error “E”, \(-20 \leq E \leq 20\), the unit is \(\mu m\).

Setting the state of the HMM is 3 (high, normal, low), each state correspondence to the number of impossible observations selected 9, the initial probability status matrix of the HMM selected is \([1/3, 1/3, 1/3]\) (the probability of three states is same), According to the size
of detection error, select threshold $T_1 = 0.05$ to determine the error status value of the discrete case. There into:

$$
S = \begin{cases}
1 & \Delta < -T_1 \\
2 & -T_1 \leq \Delta \leq T_1 \\
3 & T_1 \leq \Delta
\end{cases}
$$

(3)

According to the value size of detection error and threshold $T_2$ to discrete the error, gain access to the actual observed values. There into:

$$
O = \begin{cases}
1 & -20 \leq E \leq -16 \\
2 & -16 < E \leq -12 \\
3 & -12 < E \leq -8 \\
4 & -8 < E \leq -4 \\
5 & -4 < E \leq 4 \\
6 & 4 < E \leq 8 \\
7 & 8 < E \leq 12 \\
8 & 12 < E \leq 16 \\
9 & 16 < E \leq 20
\end{cases}
$$

(4)

When the error is predicted and calculated, need to make the discrete prediction error value convert into the discrete error correction, there into:

$P = [-18, -14, -10, -6, 0, 6, 10, 14, 18] ^T$

Selected $P$ is based on the averaging threshold of each interval $T_2$ about critical value (when $-4 \leq E \leq 4$, hold the detection error values are within the scope of the CNC controlled, at this point $P=0$).

The Experimental Analysis

Using AGPM grinding spherical curve $x^2 + y^2 = 60^2$, diameter $D = 50$ mm for example as analyzed and validate object.

First of all, processing curve by segmented 20 section, compiled the machining program, controlled the AGPM start grinding, the grinding times is 50, real-time detected every error value of each node, then, discrete the detection error and established the HMM, according to the error state when processing the last times, the error observed value, processing the current time possible distribution and probability value, calculated the expectations value of the prediction error, used the expectations value compensated the next time feed forward.

From the analysis of table 1, compared to the error compensation data of the former, the error value greatly decreased after the compensation, especially for larger error nodes, compensation effect is more pronounced; compared to the compensation variance values of the former, after compensation is far less than before compensation, explained on discrete degree of error is smaller, from the Angle of the machine processing, the smaller discrete degree error is beneficial to processing the smoother aspheric surface contour curve.
Therefore, based on the compensation algorithm of the HMM principle is an effective and feasible compensation theory.

Table 1. Compensation error of the data before and after contrast.

| Node location | The X axis error data (the units is μm) | Before the compensation | After the compensation |
|---------------|----------------------------------------|------------------------|------------------------|
|               |                                        |                        |                        |
| 1             | 19.3125                                | 18.3125                | 1.1964                 |
| 2             | 11.2500                                | 8.6313                 | -3.2498                |
| 3             | 0.2188                                 | -0.7500                | 2.5166                 |
| 4             | -4.5938                                | -3.4375                | -2.1985                |
| 5             | 2.6875                                 | 6.0313                 | -4.0671                |
| 6             | -2.8438                                | 0.8438                 | 1.7481                 |
| 7             | -1.6875                                | -1.7813                | 0.6954                 |
| 8             | -2.1563                                | -0.1563                | 1.9842                 |
| 9             | -4.0000                                | -0.9375                | -0.9006                |
| 10            | -0.5913                                | 2.2500                 | 4.6480                 |
| 11            | 2.1857                                 | -4.9688                | 2.6741                 |
| 12            | 1.9063                                 | -4.6875                | 3.9400                 |
| 13            | 6.5313                                 | -0.9688                | 5.5641                 |
| 14            | 3.0625                                 | 3.0938                 | -0.6515                |
| 15            | 3.0005                                 | -0.7500                | 2.9010                 |
| 16            | -2.0000                                | -4.9688                | 1.6404                 |
| 17            | -4.3438                                | -4.6875                | 0.6358                 |
| 18            | 1.4063                                 | -0.9688                | 1.6512                 |
| 19            | 6.2188                                 | 3.0938                 | 3.9960                 |
| 20            | -7.3125                                | -6.7500                | 1.6413                 |
| variance      | 5.9430                                 | 5.6000                 | 2.4677                 |

Conclusion

The article introduced the HM theory of the pattern recognition field to the CNC machine error compensation technology, achieved the real-time prediction for CNC machining error, and proceed predictive compensation, effectively improve the accuracy of CNC machining, meanwhile, also provided a new attempt for error compensation research of numerical control system and its similar system.

References

[1] Piao Cheng-gao, Yu Hua-dong, Gu Li-dong, et al. Proposal of New Principal for High-order Aspherical Machining by CNC Tangent Method [J]. Journal of Ji lin University, 2011, 41(7): 134~239.

[2] Yu Hua-dong, Gu Li-dong, Piao Cheng-gao, et al. Processing High-order Aspherical by CNC Tangent Method [J]. Journal of Ji lin University, 2012, 42(2): 354~359.

[3] Yu Jiang-de, Fan Xiao-zhong, Yin Ji-hao. Hidden Markov Models and Its Application to Natural Language Process [J]. Computer Engineer and Design, 2007, 8(22): 5514~5516.

[4] Liu Chun-li, Chen Shu-zhong, Han An-qi. Hidden Markov Model and Its Use in Face Recognition [J]. Computer Applications and Software, 2004, 21(4): 68~70.

[5] Hong Wen, Huang Feng-yan, Su Han. Human Gait Recognition Based on Continuous HMM [J]. Applied Science and Technology, 2005, 32(2): 50~52.

[6] He Yi, Yang Xin. Detection and Tracking of Vehicles Based on Hidden Markov Measure Field Model [J]. Applied Science and Technology, 2008, 42(2): 270~273.